

The Check Engine Light is on.
Diagnosing and Repairing Mathematics Education in Ontario:
Portfolio of Learning

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Abstract

This portfolio of learning was created to provide suggestions for improving student learning and achievement in elementary mathematics in the province of Ontario. The ideas and conclusions provided came from the combination of two different perspectives, theory and practice. Theory is shared through a review of the literature and artifacts selected from Master of Education course work. Practice is shared through student, teacher, and consultant experiences in mathematics. As a result of these combined perspectives, a comprehensive pedagogy, professional learning for educators, and effective teacher assessment and feedback were determined to be fundamental in improving mathematics learning. These suggestions are analyzed and discussed, resulting in practical implications for teachers, coaches, consultants, and administrators to improve the future learning of elementary mathematics.

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CHAPTER ONE: INTRODUCTION TO THE PORTFOLIO

Many of us have had the frightening experience of driving a vehicle when suddenly the check engine light appears on the dashboard. The fear comes from the unknown. Will I make it home? Will I make it to a repair shop? Will I damage the vehicle if I keep driving? How much is this going to cost? I suggest we are currently experiencing a similar situation with the elementary mathematics education engine in Ontario. The check engine light is on, signaled by decreasing standardized test results (Education Quality and Accountability Office, 2013, 2017) prompting headlines in the news such as “Ontario's math scores started declining as kids took the new curriculum, according to EQAO data” (Csanady, 2016) and “Ontario addresses math score decline amid worry from parents, educators” (Alphonso, 2016).

Unfortunately, unlike a vehicle, we are unable to plug the elementary mathematics education engine into a computer to diagnose the specific problems. Do we need to replace the old engine with a new one? If we keep driving without any repairs will we do greater damage? If we do not need to replace the engine, then what do we need to fix or replace?

This portfolio suggests diagnoses and repairs for the Ontario elementary mathematics education engine from two perspectives. The first perspective is based on research and could be compared to a repair manual for an engine. It provides recommendations based on the study, gathering of evidence, and the presentation of conclusions and suggestions from past engine repairs. The second perspective is based on my work and observations as an elementary mathematics consultant and could be compared to the perspective of a mechanic. It provides recommendations based on the

examination of different parts of the engine. These two perspectives will be shared through the development of a portfolio.

Preamble

This portfolio of artifacts contributes to the topic of improving elementary mathematics education in Ontario. Artifacts in the portfolio support the suggestions of

- A comprehensive pedagogy,
- Professional learning for educators, and
- Effective teacher assessment and feedback.

A review of these suggestions are shared, making use of the artifacts, to provide educators with an understanding of past, current, and recommended future instructional practices in order to improve elementary mathematics instruction in Ontario. The portfolio and its artifacts are intended to be useful as a reference for all stakeholders in the educational community interested in improving elementary mathematics through the use of a variety of strategies involving students, teachers, and administrators.

Purpose

The purpose of this portfolio is to share the knowledge I have gained through the creation of a variety of artifacts during my time as a Master of Education student at Brock University. Some of the artifacts were produced to demonstrate what I had learned through specific course requirements while other artifacts were created to apply what I had learned in my position as an elementary mathematics consultant in an Ontario school board. All of the artifacts were created through the lens of improving elementary mathematics education.

Conceptual Framework

As a starting point to improving mathematics education in Ontario, a common understanding of an effective, comprehensive pedagogy needs to be agreed upon and implemented. The Ontario Mathematics Curriculum (Ontario Ministry of Education, 2005) provides educators with common content expectations at each level from grades 1 to 8 but does not provide much guidance for how these expectations are to be taught. The National Council of Teachers of Mathematics (Leinwand; 2014) highlights “that effective teaching is the nonnegotiable core that ensures that all students learn mathematics at high levels and that such teaching requires a range of actions at the state or provincial, district, school, and classroom levels” (p. 4). What instructional beliefs, principles and practices define the effective teaching of elementary mathematics? NCTM (Leinwand, 2014) provides a list of eight teaching practices that are described as “high-leverage practices and essential teaching skills necessary to promote deep learning of mathematics” (p. 9). These eight practices include:

- Establish mathematics goals to focus learning.
- Implement tasks that promote reasoning and problem solving.
- Use and connect mathematical representations.
- Facilitate meaningful mathematical discourse.
- Pose purposeful questions.
- Build procedural fluency from conceptual understanding.
- Support productive struggle in learning mathematics.
- Elicit and use evidence of student thinking. (p. 10)

According to NCTM (Leinwand, 2014), these practices are research informed and align with much of the math education literature from the past 2 decades.

In 2010, the Ontario Ministry of Education (OME) formed a mathematics working group to review the research literature to determine next steps for improving mathematics outcomes for students from kindergarten to grade 12. As one result of this work, a publication was produced (OME, 2011) that contained seven foundational principles for improvement in mathematics. One of these principles was to “build understanding of effective mathematics instruction” (p. 6). This principle was unpacked with approximately 20 bulleted points, most of which aligned with the eight NCTM principles shared above.

While there seems to be agreement in the literature and amongst professional teaching organizations, such as NCTM and the OME, concerning effective mathematics pedagogy, there have been significant challenges in regards to the implementation of that pedagogy at the provincial, board, school, and classroom levels. This implementation must begin with professional learning for all educational stakeholders.

Ball, Hill, and Bass (2005) describe mathematical knowledge for teaching as “a kind of professional knowledge of mathematics different from that demanded by other mathematically intensive occupations, such as engineering, physics, accounting, or carpentry” (p. 17). It goes beyond mathematical content knowledge to include knowledge about how students acquire mathematical content knowledge including important ideas, models and strategies, representations, student misconceptions, and interventions. The educators of Ontario need time and focused professional learning supports to re-learn the

mathematics content themselves through conceptual understanding and to learn about effective pedagogy for teaching that content to their students.

Effective professional learning needs to begin with a shared vision. That vision needs to come from educator challenges or needs arising from an aligned, nonnegotiable, system framework concerning effective mathematics instruction. Katz and Dack (2013) confirm, “a teacher learning focus emerges from an investigation of what teachers need to learn to support what students need to learn” (p. 36). The authors emphasize that the learning need identified by teachers in turn becomes the learning need for system leaders. Focused, sustained professional learning at all levels will be a necessary component in improving mathematics education, but we also need to determine how we will know if these supports are being implemented at the classroom level.

In my role as an elementary mathematics consultant, I have frequently witnessed educators participating in professional learning concerning mathematics pedagogy. Most educators are positive and willing to try new practices in the classroom initially. However, many participants return to past practices after the professional learning has ended. In investigating further, many participants felt unsupported back in their classrooms and did not feel all the work required to change would be valued in their school. Effective teacher assessment and feedback could provide the system with multiple benefits highlighted by Fink (1999) including improving teaching, communicating the quality of teaching to others, and to know if teachers, administrators, schools, and systems are doing a good job of teaching mathematics.

Currently in Ontario, an administrator does the majority of elementary and secondary teacher evaluation for the purpose of certification because they are required to

do so by the Ministry of Education. During this evaluation, there is some surface level discussion between the administrator and teacher about general ways to improve teaching as part of the standardized process. I feel these evaluations rarely impact teaching practice because the primary purpose of the evaluation is to provide a satisfactory or unsatisfactory rating. Summative teacher evaluations for the purposes of certification or re-certification are necessary, but our system needs to reflect on other purposes for teacher evaluation to improve student, teacher, and system learning of mathematics.

There are a variety of studies that focus on ways to measure teacher effectiveness. In my review of the literature, I found one common foundational principle in these studies of teacher evaluation regardless of whether the evaluation purpose was summative or formative. That common principle was to collect evidence from a variety of sources (Berk, 2005; Fink, 1999; Cantrell & Kane, 2013; Reddy, Fabiano, & Jimerson, 2013). These sources included teacher self-evaluations, student assessment and perception data, and outside observer data that would include colleagues and administrators. The inclusion of multiple sources would effectively balance the evaluation process while aligning system understanding of best instructional practices for teaching mathematics.

The artifacts included in this portfolio support the suggestions for improving elementary mathematics education in Ontario listed above. Pedagogy, professional learning, and teacher assessment and feedback each have the potential to provide a positive impact to elementary mathematics teaching and learning on their own. However, for a more significant impact, a comprehensive approach adopting all of these suggestions is needed.

Artifact Selection and Objectives

This portfolio provides background knowledge pertaining to the current issues in elementary mathematics teaching and learning in Ontario. It offers teachers, administrators, and other educational stakeholders practical suggestions for improving mathematics instruction at a classroom, school, and system level. These suggestions could also extend to other subject areas outside of mathematics and beyond the elementary level to secondary and postsecondary.

Artifact Selection

The artifacts included in this portfolio come from two sources. Most of the artifacts were produced as part of the course requirements during my Master of Education (MEd) program. The remaining artifacts were produced in my role as an elementary consultant for an Ontario school board during this same time period. The artifacts were all selected through the lens of improving mathematics education in Ontario.

Specific Objectives of this Portfolio

- To review the history of elementary mathematics education in Ontario
- To describe the current situation of elementary mathematics education in Ontario
- To identify specific issues in regards to elementary mathematics instruction
- To share an outline of the components of a comprehensive mathematics pedagogy
- To offer recommendations regarding the implementation of professional learning supports to improve mathematics instruction

- To examine the role of teacher assessment and feedback in improving mathematics teaching and learning
- To share a variety of artifacts produced as a student in the MEd program and as an elementary mathematics consultant
- To provide practical suggestions for a comprehensive approach to improving mathematics teaching and learning in Ontario for a variety of educational stakeholders

Rationale for Research

During the past 5 years in Ontario, elementary mathematics student achievement results at grades 3 and 6 as measured by EQAO (2017) have decreased. The EQAO (2016) document titled *EQAO Highlights of the Provincial Results*, highlights that while the percentage of grade 3 and 6 students achieving the provincial standard or higher has steadily increased in reading and writing over the past 5 years, there has been a decrease in achievement in mathematics over the same time period. In grade 3 mathematics, the percentage of students at standard or higher has decreased from 71% in 2010 to 63% in 2016. In grade 6 mathematics, the percentage of students at standard or higher has decreased from 61% in 2010 to 50% in 2016 (pp. 2-3). The 2016 cohort results comparing the EQAO mathematics results of grade 6 students to their performances in grade 3 were even more concerning. For those students who had achieved the provincial standard in grade 3, 21% had dropped below the standard in grade 6 compared to only 4% of students who had not achieved the standard in grade 3 but rose to the standard or higher in grade 6 (p. 4).

These decreases have caused the OME (2015) to wonder, “Have we been wrong in our assumptions about how to make improvements in mathematics education or are we are on the right track and just need more time?” (p. 1). In order to answer this question, the OME (2015) formed a group of experts from a variety of backgrounds to offer their thoughts. This group provided four recommended areas of focus for educators:

1. Mathematics content knowledge for teaching
2. Mathematics pedagogical knowledge
3. Deep knowledge of the mathematics curriculum
4. Precision in mathematics assessment. (p. 1)

These recommendations focus the solution for declining elementary mathematics achievement on the knowledge needed for teaching mathematics including content, pedagogy, and assessment that align with the topic of comprehensive pedagogy that was previously discussed. However, other questions arise in regards to improving math achievement provincially. What types of professional learning will be most effective in improving educator understanding of the knowledge for teaching mathematics? How will systems know if this knowledge is being applied in the classroom? How will teachers receive feedback while trying to apply this knowledge in the classroom?

This portfolio addresses these questions through the development of the enclosed artifacts as a means of providing one possible comprehensive approach to improve elementary mathematics education in Ontario.

Scope and Sequence of the Portfolio

The basic scope and sequence of this study are provided. First, a historical review of elementary mathematics education in Ontario is provided. Current understandings of recommended instructional practices are examined in relation to actual classroom practices observed and shared by educators. A theoretical framework designed to improve the outcomes of elementary mathematics instruction and student achievement in Ontario is explored and supported through a portfolio of artifacts that highlight the importance of a comprehensive mathematics pedagogy, professional learning for educators, and effective teacher evaluation.

A limitation of this study is the focus on elementary mathematics instruction. There are recommendations provided that could extend into secondary and postsecondary instruction and to other subject areas, but a lens of elementary mathematics instruction has been used in the development of this study.

Outline of the Document

In Chapter One, an introduction to the topic and portfolio is provided. The purpose of the artifacts in relation to the area of academic focus is described. Chapter Two begins with an autobiographical sketch sharing my personal philosophy of education and how it relates to the overall development of the artifacts in the portfolio. This chapter continues with an overview of the literature related to effective mathematics instruction, professional learning, and teacher assessment and feedback. Chapter Three of the portfolio outlines each of the artifacts and their contribution to the overall theme of improving mathematics education in Ontario.

CHAPTER TWO: BACKGROUND

This portfolio was developed to provide educational stakeholders with suggestions for improving elementary mathematics education in Ontario. These suggestions were authored as a result of a reflective process involving my experiences as an elementary teacher and consultant in an Ontario school board in addition to my course work and research as a student in the Master of Education program at Brock University. This chapter begins with a personal autobiography to highlight some of my personal and professional experiences that have shaped my continued passion and interest for teaching and learning mathematics. In Appendix A, I have included a curriculum vitae, which outlines a more detailed description of my educational and professional experiences to date.

Following the personal autobiography, a review of the literature is provided to introduce a recommended pedagogy for mathematics in Ontario, suggest ideas for more effective professional learning, and to argue for formative assessment and feedback for teachers, in order to improve student achievement in mathematics in the province of Ontario.

Personal Autobiography

My name is Ed Enns, I grew up in a small town in southwestern Ontario and attended the public elementary schools there from kindergarten to grade 8. My parents were both teachers. My mother taught elementary and my father, secondary. Learning was always encouraged in our home and my parents were always there as educational supports to practice multiplication facts, organize notes, and prepare for tests and projects.

Elementary Experiences

Starting with my earliest memories of mathematics classes in elementary school, I recall a repeated process of traditional, direct instruction that was generally followed from grade 1 to grade 8. The teacher would stand at the front of the class and demonstrate procedures or provide definitions on the chalkboard. We would be expected to copy this work into our notebooks. During this process, the focus was predominantly on the steps to do the mathematics procedures with little to no explanation as to why or how the procedures worked. I have a specific memory of a class during which we were learning how to do column addition with regrouping. The teacher had just demonstrated an example in which he carried one 10 from the ones column to the top of the 10s column as a one. After the teacher completed the explanation of the entire procedure, a classmate asked why he had put the one above the 10s column. The teacher's response was, "Don't worry about why the one goes up there just put it above the tens column." These early experiences contributed to an early personal belief that mathematics was not a subject to be understood but one in which I was to memorize steps and procedures.

Following the teacher explanation and note taking, we would usually be provided with computations or exercises to complete to practice the procedure that had just been shared by the teacher. I recall these times as quickly becoming monotonous and boring as we just kept repeating the same procedure with different numbers over and over again in a silent classroom. Upon completing pages of computations, we usually were presented with a series of word problems. In grade 3, I remember coming to a math class time saving epiphany. I really did not need to read through all the word problems in order to answer them. We had been learning about addition and I had just completed pages of

addition computations. I read through the first word problem and realized the answer would be determined by using addition. Then I concluded that all the word problems were probably going to be addition problems. Therefore, in order to save time, I just found the two numbers in each problem and added them together to get the answer. Then I just changed the question in the problem to an answer statement and I was done. During this time in elementary school, most math word problems had one answer that was to be done one way and the emphasis was on the correct answer and the proper format and conventions used in the solution.

Our mathematics homework usually consisted of memorizing our basic facts, additional computation questions, and word problems. This work further consolidated my belief that mathematics was a series of steps and facts to be memorized. It was a boring and monotonous subject that could not be understood but was something I had to do. At times, it almost felt as if I was a pet performing tricks that made the adults happy. I do not recall enjoying math during this time of my life; however, I always received good grades because I was a great memorizer and could recall facts and procedures. As I finished my elementary education and was about to begin high school, I recall a nervous feeling about mathematics. It was as if I was walking on the edge of a cliff with the comfort and solid ground of high grades during my elementary days on one side but the chasm of not really understanding what I was doing on the other. This feeling would intensify as I made my way through secondary mathematics classes.

Secondary Experiences

In secondary school mathematics classes, I continued to experience traditional instructional methods that did not differ much from elementary. The mathematics was

more complex, there was a lot more homework, and the program was usually based on a textbook. During this time, I remember spending a lot of time working on homework questions and problems that I did not understand. In mathematics class, if I did not understand a concept or procedure I was often too embarrassed to ask for clarification because I assumed everyone else understood the material and I would look “dumb.” When I got home, I would be stuck on questions involving these same concepts and my coping mechanism was to look in the back of the text book for the right answer and then attempt every manipulation of the numbers or variables that I could think of to make my answer match the one in the back of the book.

Upon reflection, I recognize that these secondary mathematics experiences were damaging for me as a learner of mathematics in a number of ways. The combination of a lack of conceptual explanation during traditional instruction and not asking for additional help and clarification was creating foundational gaps in my mathematical learning that would grow wider in later secondary Algebra, Functions, and Calculus courses. However, the greatest negative effect of this time was on my own belief in my ability to be successful in mathematics. The “mathematical cliff” based on memorization I had felt I was teetering on at the end of elementary school had given way and I was falling into the abyss. Not surprisingly, my grades decreased as I continued through high school and although I passed my final courses in Calculus, Functions, and Algebra, I would not pursue mathematics related disciplines in university due largely to my lack of self-efficacy.

Through my experiences of working with hundreds of elementary mathematics educators and parents as a consultant, I have been surprised to discover that the majority

of these adults, 70-80% by my estimate, had similar negative experiences when it came to their mathematics education both in instructional methods and a lack of success in secondary mathematics. The remaining minority who were successful in secondary mathematics report that they were taught in a similar traditional direct instruction pedagogy emphasizing procedures and memorization but were able to understand the mathematics on their own. Most of this group also reported enjoying the subject. These people often went on to math related professions such as engineering, architecture, and secondary and postsecondary mathematics education. Many people in this minority do not realize that most adults did not have positive outcomes in terms of marks and efficacy in secondary mathematics and they do not understand why mathematics pedagogy should be changed because it worked for them. Understanding and considering both of these perspectives has become important for me in my role as an elementary mathematics consultant.

Postsecondary Experiences

In university, I graduated with a Bachelor of Arts Degree in Honors English. My postsecondary experiences in mathematics at this time were limited to a few courses involving statistics and a computer programming course. Upon completion of my Bachelor degree, I enrolled in a Bachelor of Education program where I revisited elementary mathematics from the different perspective as a teacher candidate.

It was here that I began to deeply understand some foundational mathematical concepts such as place value in standard algorithms and the distributive property by preparing lesson plans for assignments and during teaching practicums. I began to see mathematics differently, as a discipline that could be understood. Procedures that I had

previously memorized started to make sense to me as I learned the why and how of mathematics. The more I learned, the more excited I became not only as a learner but also in considering the opportunity to teach mathematics to children. I decided then and there that I would teach mathematics differently than the way I was taught. I would teach mathematics so students would understand and enjoy the subject. Upon completion of my Bachelor of Education program, I began my career in education as an elementary teacher with a southern Ontario school board.

Teaching Experiences

As I entered the real world, I found teaching at the elementary level to be extremely challenging and at times overwhelming. Besides mathematics, I was also teaching reading, writing, science, social studies, physical education, visual arts, and music. Planning, teaching, and assessing all of these subjects felt like I was spinning plates at a talent show with each subject representing a plate. Even though I could spend hours preparing for each subject, in order to survive I needed to spread those hours out to have time to plan for all the subjects so I would not drop any plates. As a beginning teacher, I was always looking for ways to save time and a mathematics textbook was the ideal support. With the textbook, the planning was done for me; I just needed to assign the pages and take up the work. The textbooks were usually authored by talented mathematicians and educators and contained many good ideas, questions, and problems. However, I soon discovered the effective use of a text still requires a knowledgeable teacher.

After a few years of relying too much on a math textbook, I found I was not digging into the math I was “teaching” to understand the concepts more deeply in order

to help students understand the mathematics. I soon found that despite my best intentions, I had reverted back to teaching mathematics as I was taught emphasizing the “surface” mathematics of memorizing facts and procedures through practice. My students were replicating the results of their parents’ generation. A minority of students seemed to understand the mathematics and enjoy the subject. The majority did not like math class and experienced varying amounts of success depending on how well they could memorize facts and procedures. As a teacher, I knew something had to change and my students showed me how.

During a grade 6 math class, I was taking up a math problem with my students. The problem involved multiple steps including area, perimeter, scale, multiplication, and addition. One of my students came up with an answer that I had difficulty following and understanding but she had the correct final answer. Instead of dismissing the answer because it was different from the textbook example and how I would have done it, I handed her the chalk and invited her to explain her thinking at the front of the class as I took her seat at her desk. It was this moment that became the turning point for how I taught mathematics.

Novel things were happening in this math class. Most of the students were actually smiling and paying attention to the speaker at the front of the room. This student explained her answer in a way that her classmates could understand. The students were not just listening but also asking follow-up questions for clarification and sharing additional ideas. The students were taking ownership of the math and walls were coming down in order for them to deepen their collective understanding of the concepts. As a teacher, I was hooked. How could I get students more actively involved in the teaching

and learning of mathematics? Where could I find similar investigations that would spark deeper thinking? How could I deepen my own understanding of the mathematics to know what tasks to select? What does a truly effective elementary mathematics program look and sound like? During the next 10 years of teaching, I searched for answers to these questions through reading, professional learning, and trial and error. Eventually, these experiences led to facilitating some teacher workshops in mathematics and to a position as a kindergarten to grade 8 mathematics consultant for a southern Ontario school board.

Consultant Experiences

As an elementary mathematics consultant, I had entered a new educational world. I had time to read, reflect, and discuss ideas focused on the single subject of mathematics. I became a member of organizations such as the National Council of Teachers of Mathematics (NCTM), the Ontario Association for Mathematics Education (OAME), and the Ontario Mathematics Coordinators Association (OMCA). My membership in these organizations introduced me to mathematics educational research from around the world and to colleagues from around North America in similar positions to connect, reflect, and collaborate.

Some of my early influences in math education reading and research included *About Teaching Mathematics* (Burns, 1995), *Elementary and Middle School Mathematics*, (Van de Walle, Karp, & Bay-Williams, 2004), *Adding it Up* (National Research Council & Mathematics Learning Study Committee, 2001), *Children's Mathematics: Cognitively Guided Instruction* (Carpenter, Fennema, Franke, Levi, & Empson, 1999) and *Young Mathematicians at Work: Constructing Multiplication and Division* (Fosnot & Dolk, 2001). These books deepened my mathematical content

understanding and helped shape my pedagogical philosophy for teaching mathematics that differed from the traditional mathematics instruction I had experienced that was still being used in most classrooms. It soon became apparent that there were other members of the elementary math community in Ontario who were looking for change.

In 2002, the Ontario government developed an Early Math Strategy (grades K to 3) to improve early mathematical understanding and skills. As a part of this strategy, an expert panel in early learning and teaching of mathematics was formed to provide ideas and advice pertaining to teaching and learning mathematics in the primary years. This panel was comprised of researchers, consultants, administrators, and teachers from across Ontario. The panel collected, reviewed, and synthesized available research as a foundation to the resulting Report of the Expert Panel on Early Math (OME, 2003). This process was continued into the junior division with the completion of The Report of the Expert Panel on Mathematics in Grades 4 to 6 in Ontario (OME, 2004). General messages and important ideas concerning teaching and learning mathematics in these reports were aligned. I was honored to be included as a member of the group who authored the junior expert panel report.

These reports suggested significant changes to the traditional pedagogy of elementary mathematics. Suggested changes to instruction in the Expert Panel Report (OME, 2004) included new emphases on conceptual understanding, problem solving, students working in groups, active learning, and starting and building on student knowledge within a topic. From 2004 to 2008 the Ministry of Education provided professional learning and resource guides for kindergarten to grade 6 mathematics teachers across the province based on the ideas presented in the expert panel reports.

From 2004 to 2006, I was seconded to the OME as part of a working group that developed some of the elementary math professional learning supports and resource guides that continue to be used in the province today.

The provincial reports and instructional materials from this time provided a foundation for change in elementary mathematics in Ontario. These new ideas influenced some of the changes to the Ontario Mathematics Curriculum that was revised in 2005 including a new emphasis on the processes of learning mathematics. The OME continues to provide elementary mathematics resources and research that build upon, refine, and extend the thinking that was shared in these foundational materials.

I returned to my role as a consultant after my secondment to the OME in the fall of 2006 with a new challenge. As a new consultant and while working at the Ministry, I had spent much of my time reading, researching, and reflecting upon mathematics education in order to help author instructional materials. As a result, I had a much deeper understanding of the math content knowledge needed for teaching and the recommended pedagogy of how to teach mathematics. The new challenge was how to effectively share this knowledge and convince elementary mathematics teachers to change their instructional practices and possibly their beliefs about how children learn mathematics.

It soon became apparent that the initial strategy of providing teachers with some training and instructional materials was not enough to bring about systemic or even school-wide changes to mathematics instruction. Even with a revised curriculum, some dedicated professional learning time for all teachers of mathematics and supporting teaching guides, there were limited changes to instruction in a minority of classrooms. Through my reflections on professional learning experiences, observations, and

conversations with educators, some barriers to systemic change that were identified included:

- Insufficient depth of understanding of the recommended pedagogy for teaching elementary mathematics amongst teachers and administrators;
- Insufficient professional learning time and support focused on mathematics for educators;
- Models of professional learning with limited effectiveness;
- Shifting school, board, and provincial professional learning foci;
- A generalist model for elementary teaching that limits the amount of planning time teachers have for a single subject;
- Absence of provincial or board mandate to change mathematics instruction;
- Identification of instructional strategies and supports for students with learning gaps in mathematics.

The systemic results of these barriers have included limited adoption of the recommended pedagogy. Currently, there is a continuum of varied instructional practice with teachers using the recommended pedagogy as outlined in the provincial panel reports and teaching guides on one side and teachers teaching using traditional direct instruction methods on the other. In between the two ends of the continuum are teachers who are using some of both methods due to the barriers listed above. In some schools, there are classrooms from all three places on the continuum. A common misconception shared by the media is that the new recommended elementary mathematics pedagogy has been adopted in all Ontario schools and, therefore, is the cause of declining EQAO results. Based on my experiences, observations, and conversations, I would argue that

there has been limited adoption of this pedagogy to limited degrees and this limited adoption may be contributing to declining EQAO results.

In an attempt to address some of these barriers, I have turned my personal learning focus toward closing learning gaps in mathematics, effective models of adult education, and implementing change. I enrolled in a Master of Education course at Brock University in the Teaching, Learning, and Development pathway to support my learning goals. During this time, I have attempted to put theory into practice and practice into theory by trying to implement what I have learned through my courses at Brock during this time in my work with educators and by focusing my study and research at Brock through the filter of the needs of elementary mathematics students and educators.

A review of the academic literature will be provided to address my suggestions for improving elementary mathematics education. The review will also provide a foundation for the knowledge and experiences shared later in the artifacts.

Review of Related Literature

This review of the literature examines the suggestion of improving elementary mathematics education in Ontario through a comprehensive pedagogy, professional learning for educators, and effective teacher assessment and feedback. While I acknowledge this review is not exhaustive, it includes research uncovered during Master of Education course work and during investigations as an educational consultant. A more recent search for relevant literature was conducted for articles that had been published between my previous research work and the authoring of this project.

A Comprehensive Pedagogy

In recent years, there has been a change in focus for mathematics education imparted to school boards by the OME. An earlier focus of problem solving and reasoning (OME, 2011) has shifted into what is described as a balanced approach that includes problem solving and reasoning but also highlights skills, and direct instruction (OME, 2017a). This shift is also beginning to appear on Ontario School Board web sites describing current math education approaches as balanced (Ottawa Carleton District School Board, 2017; Toronto District School Board, 2017) or comprehensive (Waterloo Region District School Board, 2017; York Region District School Board, 2017). A recent search of the literature did not provide results containing the terms balanced or comprehensive mathematics instruction as keywords suggesting that the impetus for change in Ontario mathematics education came from other sources. I suggest that the terms comprehensive and balanced mathematics instruction have arisen in Ontario as a response to pressure for change to the perceived, recommended mathematics pedagogy from two sources, the media and Ontario mathematics educators.

The origins of comprehensive or balanced mathematics in Ontario. In Ontario in recent years, the media has highlighted declining mathematics results in EQAO at grades 3 and 6 and connected this decline with the provincial emphasis placed on the new math pedagogy described as discovery math. This pedagogy is criticized for a lack of emphasis on basic facts and procedures, and direct instruction (Alphonso, 2016; Csanady, 2016). Most of these recent media articles base their criticisms and suggestions for change from a C.D. Howe sponsored commentary *What to Do about Canada's Declining Math Scores* (Stokke, 2015). Stokke, an Associate Professor, Department of Mathematics

and Statistics, at the University of Winnipeg has authored or is quoted in numerous articles in publications across the country in the past few years criticizing current pedagogies and providing suggestions for change ("Something doesn't add up with Alberta's math", 2017; Staples, 2017; Stokke, 2017). In the previously mentioned commentary and articles, Stokke criticizes what she describes as discovery based instruction and calls for more direct instruction and an emphasis on memorization of basic facts. These public criticisms played a role in changing the OME's messaging concerning effective mathematics instruction to a more holistic description including some of the suggestions made in the media. Many Ontario mathematics educators also welcomed this change in emphasis from the focus on teaching through problem solving.

In Ontario, the Ministry of Education published support documents, *K-6 Guides to Effective Instruction in Mathematics* (2003–2008), to provide teachers with practical ideas for putting theory into practice. These guides were based on reviews of research concerning effective mathematics instruction included in earlier provincial expert panel reports on mathematics in the primary and junior grades (OME, 2003, 2004). These guides and reports presented new ways of teaching mathematics that emphasized conceptual understanding and teaching through problem solving (TTPS). *The Report of the Expert Panel on Early Math* (OME, 2003) provides an explanation of TTPS that differs from earlier discovery-based definitions:

Problem solving is more than the application of skills. Problem solving in a classroom generally begins with the teacher presenting the problem, students exploring and working on a solution to the problem, and then teacher and students consolidating and reflecting. (p. 16)

Placing further emphasis on TTPS, *The Ontario Curriculum Grades 1-8 Mathematics* (OME, 2005) describes problem solving as “the basis of effective mathematics programs and should be the mainstay of mathematical instruction” (p. 11). TTPS was a new and revolutionary approach for most elementary mathematics educators in Ontario. It took the traditional model of teaching mathematics most educators had experienced as students and teachers and turned it upside down. It was a complex approach that required a lot of study and practice to become comfortable with. As a result, TTPS became a focus and emphasis during the majority of professional learning in elementary mathematics education in Ontario over the past 10 years. Through professional learning survey data, many Ontario teachers reported a change in their practice and a higher comfort level with the TTPS approach; however, there were other unintended consequences.

Due to the often singular focus of professional learning on TTPS, many educators believed this new approach to learning mathematics meant that basic facts and procedural knowledge should be de-emphasized or no longer be taught and that the role of practicing new skills to develop new conceptual and procedural knowledge should be greatly diminished. Many Ontario elementary mathematics teachers using TTPS reported levels of frustration as EQAO and classroom student achievement results declined. The media criticized the TTPS approach, some parents questioned the current pedagogy, and the teachers themselves questioned the role of TTPS in mathematics instruction and the inclusion of other approaches including basic facts and practice. As a result of this frustration, I believe the OME responded by changing the focus for mathematics education in Ontario. In discussing the recent change of focus to a more balanced or comprehensive approach to teaching mathematics (OME, 2017a), most educators

welcome this new direction that explicitly highlights not only TTPS, but also direct instruction and practice.

The publicly announced balanced approach to mathematics education addresses some of the concerns raised in the media and the frustrations shared by Ontario educators; however, it also raises more questions. What does a balanced approach to teaching mathematics really mean? What instructional approaches are included in a balanced or comprehensive math program? Should the same amount of time be spent on each approach? How do TTPS and direct instruction co-exist in the same program? What do these terms really mean to educators in the math classroom?

Defining a comprehensive pedagogy. I prefer the term comprehensive over balanced when describing recommended mathematics pedagogy. One meaning of the word balanced is equal. Using this meaning, educators could perceive that an equal emphasis and amount of instructional time should be given to each of the different elements and approaches that make up a balanced mathematics program. The word comprehensive suggests addressing all parts of something without suggesting equality between the parts (comprehensive, 2017). In the context of a comprehensive mathematics program all instructional elements and approaches are considered; however, the amount of time and emphasis would vary. What are the main components that should be included in a comprehensive mathematics pedagogy?

Teaching through problem solving. Teaching through problem solving should be the foundational component of a comprehensive mathematics approach to instruction. The National Council of Teachers of Mathematics *Principles to Actions* (Leinwand, 2014) identified tasks that promote problem solving and facilitating mathematical student

discourse as two research-informed, essential teaching practices for deep mathematical learning. The majority of the literature I reviewed supported the idea of teaching mathematics through a problem-solving approach (Boaler, 2016; Fast & Hanks 2010; Lester, 2013; Rittle-Johnson & Star, 2007; Schmidt, Loyens, Van Gog, & Paas, 2007).

Fewer studies argued against the perceived TTPS approach, but those that did tended to originate in educational psychology research (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Kirschner, Sweller, & Clark 2006; Stokke, 2015). In Stokke's *What to Do About Canada's Declining Math Scores*, the majority of sources referenced in this work originate in the educational psychology community with few sources from the mathematics education discipline. In her interpretation of her reviewed research, Stokke concluded "Evidence shows that direct instructional techniques work better than discovery-based techniques, so teachers should follow an 80/20 rule, devoting at least 80 percent of their math instructional time to direct instructional techniques" (p. 13). Upon closer examination of Stokke's work and the literature she references, I concluded that the terms teaching through problem solving and discovery based learning do not describe the same pedagogy, yet much of the educational psychology research referenced in Stokke's commentary actually supports teaching through problem solving over direct instruction (Alfieri et al., 2011).

Before proceeding, it will be necessary to clarify what is meant by the terms discovery based learning and teaching through problem solving. Some authors included problem-based learning in a list with discovery learning, inquiry learning, and experiential learning, describing them as equivalent approaches under the umbrella of a minimally guided approach to teaching and learning (Kirschner et al., 2006; Stokke,

2015). Similar interpretations of teaching through problem solving are often used in the media. These definitions and interpretations suggest that students are given problems to learn new mathematical content through "discovery" with little or no guidance from the teacher and that knowledge is not presented or explained; therefore, students must construct it on their own. Discovery based definitions are often used in educational psychology articles such as those referenced in Stokke and these definitions usually reflect early ideas of constructivism and problem-based learning. They do not align with the definition of teaching through problem solving being used in Ontario.

In Ontario, *The Report of the Expert Panel on Early Math* (OME, 2003) provides an explanation of TTPS that differs from earlier discovery-based definitions.

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In the OME (2006) publication, *A Guide to Effective Instruction in Mathematics, Kindergarten to Grade 6 – Volume Two*, the TTPS process is described within a three-part lesson framework. The third part of the lesson described as reflecting and connecting outlines teacher actions some of which include bringing students together to share their work and ideas, reviewing and analyzing student work, highlighting mathematical concepts, and clarifying misunderstandings. The omission of the consolidation and reflection portion of TTPS in discovery based descriptions and criticisms of TTPS is significant as the instructional approaches being suggested in this part of TTPS align with

some of the key suggestions for mathematics instruction made in the research being used to criticize the approach.

In her commentary, Stokke (2015) makes references to the work of Kirschner et al. (2006) and Alfieri et al. (2011) to seemingly support her conclusion that direct instruction is the most effective approach for math education. However, both Kirschner et al. and Alfieri et al. recommend the use of worked examples as a powerful instructional approach that is included in the Ontario TTPS approach. Alfieri et al. also recommend “tasks requiring learners to explain their own ideas and ensuring that these ideas are accurate by providing timely feedback” (p. 13), an idea that is echoed in third part of the lesson during TTPS.

At first glance, there appears to be a great divide between two camps of research concerning TTPS. However, on a more detailed examination of the literature, the two sides appear to be much closer together and in agreement on many topics. Both sides would agree that unassisted discovery based learning is not an effective instructional approach for mathematics education. A guided problem-solving approach that scaffolds learning by important mathematical ideas and according to student learning needs would be most effective. This approach should allow students to develop their own thinking and ideas to be shared through worked examples that are analyzed and discussed to clarify learning and misconceptions. Teaching through problem solving should be the cornerstone of an effective comprehensive mathematics program and take up the majority of instructional time; however, it is not the only component of a comprehensive mathematics program.

Developing procedural fluency through conceptual understanding. An effective mathematics program needs to include the development of procedural fluency that is built upon conceptual understanding and reasoning. As a result, students will look to the numbers and context first in order to select the most appropriate procedure from an inventory they have developed over time (Leinwand, 2014).

During discussions about elementary mathematics at parent nights, during parent conferences, or in social situations, most adults identify the memorization of basic facts and procedures as being most important or valued part of mathematics learning. This value is most often derived from their own understanding of mathematics education based on their experiences as students. As elementary students, the majority of these adults memorized isolated facts through repetition often including the use of flashcards and worksheets with the emphasis on recalling answers, not on making sense of the operations and answers by exploring number relationships. This traditional practice of teaching facts and procedural fluency in isolation can negatively impact student confidence in their ability to do mathematics and can begin to cause math anxiety (Ashcraft, 2002; Boaler, 2015; Ramirez, Gunderson, Levine, & Beilock, (2013). Students may begin to believe that mathematics is not a subject to understand and use reason but one that requires the isolated memorization of steps shown by the teacher.

Instead, students should be encouraged to explore the underlying concepts, relationships, and properties within and between the operations (Fuson, Kalchman, & Bransford, 2005; Leinwand, 2014). As Fosnot and Uittenbogaard (2007) stated, “The issue here is not whether facts should eventually be memorized but how this memorization is achieved: by drill and practice, or by focusing on relationships” (p. 7).

Learning the basic facts and procedures through number sense will enable students to have better recall and a broader knowledge of calculations and procedures than parents who received traditional instruction through isolated memorization (Fuson et al., 2005, Kamii, 1985).

How students learn their basic facts and procedures can begin to shape their beliefs about mathematics and learning. Students learning through isolated memorization may repeatedly experience getting wrong answers without understanding why the answers are wrong. These students may begin to believe they can never be good at math because they have difficulty memorizing things. Students learning through number sense may also make mistakes in learning facts and procedures but can understand and learn from their errors by examining the relationships and underlying concepts. These students may begin to believe that mathematics can be understood and that you can learn from your mistakes and through hard work and practice. Learning facts and procedures through conceptual understanding not only provides students with an important foundation for number sense but also for a growth mindset (Dweck, 2006) in which students believe intelligence can be attained and grown through persistence and exercise.

Developing a growth mindset. As an elementary teacher, I participated in some parent interviews during which a child's academic progress was shared and the overall mathematics mark was lower than hoped for. In discussing the lower than desired result, the parent would point out that their child was probably never going to be good at math because they had never been good at math. It was as if they believed there was a math gene and if you were not born with it you could not do well in mathematics. These same

parents did not make the same types of statements when discussing other subjects such as language, physical education, or the arts.

The way in which people generally think about learning and intelligence can be described in two ways. Those with a fixed mindset believe you are born with a certain amount of intelligence that will not change. Juxtaposing this view are individuals with a growth mindset who believe they can grow their intelligence over time (Blackwell, Trzesniewski, & Dweck, 2007; Dweck, 1999, 2007). The parents mentioned above seemed to believe in a fixed mindset when it came to the subject of mathematics. This same belief occurred with students in their children's age group when more students had a fixed mindset in mathematics than any other subject area (Dweck, 2014). During one of my Master's classes, we were asked to describe our best and worst educational experiences as students. The class contained students from a range of age groups and backgrounds; however, all of us identified the same subject as our worst educational experience, mathematics. When asked why, the class identified similar reasons for their choice such as not being able to understand mathematics during class, making mistakes over and over again when doing the homework, and not knowing why and then feeling dumb when others had the right answer. Why does the subject of mathematics seem to cause more of a fixed mindset when it comes to learning?

Part of the answer may lie in the instructional techniques used historically in an elementary mathematics classroom. Most elementary teachers are generalists, teaching more than one subject. This reduces the amount of time teachers have to plan for their different subjects. As a result, especially at the beginning of their careers, many teachers rely on teaching how they were taught. In most cases, the traditional elementary

mathematics classroom would consist of direct instruction followed by memorization and practice. It is a pedagogy that typically begins with a teacher telling the math to the students who are encouraged to write it down so they can commit it to memory.

Sometimes the instruction comes from a textbook. In either case, there is often a lack of investigation into underlying concepts and usually little time for student questions to deepen their knowledge. This approach encourages the isolated memorization of facts, concepts, and procedures followed by practice questions that typically have one correct answer, procedure or strategy. Boaler (2013) states, “if students are working on short, closed questions that have right or wrong answers, and they are frequently getting wrong answers, it is hard to maintain a view that high achievement is possible with effort”(p. 146). Imagine being a math student who did not understand the mathematics in class and then was given a number of practice questions from the textbook to do for homework. After trying to answer the questions, you turn to the back of the book only to discover you are wrong again. What does this do to your mindset as a mathematics student? One study found that students who reported doing more mathematics homework than their peers actually did worse on an international standardized assessment (Kitsantas, Cheema, Ware, 2011). Some traditional mathematics instructional techniques can contribute to causing or solidifying fixed mindsets in students; however, this effect is intensified when the teacher possesses a fixed mindset.

Through her research, Dweck (2014) reports that generally 40% of students have a fixed mindset, 40% have a growth mindset, and 20% show traits of both mindsets. She goes on to share that the number of students with a fixed mindset is higher when asked about the subject of mathematics than in other areas (p. 2). The vast majority of

mathematics teachers I have worked with who teach grades 1 to 6 do not hold a degree or have additional qualifications in mathematics. In the United States, some estimate the number of elementary math teachers with a degree in mathematics to be less than 5% (National Science Foundation, 2014). In my discussions with hundreds of Ontario elementary mathematics teachers, many have shared similar stories of their own mathematics education. As students, most of these teachers reported that they did not understand math but they were good at memorizing the facts, procedures, and rules. They reported getting good math grades but feeling like imposters because they really did not understand the math. This memorization of math worked well until high school when their achievement dropped. I contend that the majority of elementary mathematics teachers, grades 1 to 6, experience discomfort when teaching mathematics and most have a fixed mindset when it comes to their own abilities to learn mathematics based on their experiences as students. If teachers have a fixed mindset in their own abilities to learn mathematics how will it affect the students they teach?

We teach who we are. Palmer (1997) argues that teaching, in part, is a reflection of the soul, of the thoughts and beliefs of the teacher. These thoughts and beliefs will influence and affect the students being taught. Therefore, it is important to know one's self in order to deepen everyone's learning (pp. 1-2). Beliefs teachers hold affect what teaching strategies they employ and how they view their students as learners (Kistner, Otto, Büttner, Rakoczy, & Klieme, 2015). Teachers with a fixed mindset are likely to believe that their students have a static amount of intelligence when it comes to learning mathematics that could not be changed through teaching. Rheinberg (1980) found that in classes taught by a teacher with a fixed mind set, students demonstrating low

achievement at the beginning of the year also demonstrated low achievement at the end of the year. In classes taught by a teacher with a growth mindset, many of the low achievers at the beginning of the year improved to become medium to high achievers.

If teachers are aware of their own fixed mindset when it comes to mathematics they may be able to work towards a growth mindset and a realization that they can learn and understand mathematics. When teachers come to this realization, they believe their students can also develop growth mindsets in mathematics as they learn and grow along with them. As an education consultant, I have worked with elementary teachers in mathematics professional learning focused on understanding the underlying concepts in the mathematics they were teaching. After the sessions, many teachers shared their excitement in understanding mathematics for the first time. One could sense a shift in beliefs as these teachers were looking forward to sharing their new understanding with their students through changes in their instructional strategies and philosophy in the math classroom. Some teachers asked an important question: How could we promote more of a growth mindset in our students when it comes to mathematics?

Perhaps the key message for students should be that learning comes from effort and it takes time and from the willingness to take risks and make mistakes (Boaler, J., 2015). In two studies (Blackwell et al., 2007; Good, Aronson, & Inzlicht, 2003), grade 7 students who were experiencing difficulty in mathematics were split into two groups. The experimental group learned about brain plasticity and its ability to grow with exercise like other muscles in the body. They learned that the brain made new connections when they made mistakes and learned something new. The control group of students was taught specific study skills to improve learning. The experimental group reversed their

downward achievement trend while the control group continued to decline. Similar results were found in other studies at the college level (Aronson, Fried, & Good, 2002). In addition to learning about the brain, students need to learn that math and science geniuses were not born with their genius. It was their passion for learning about the subject and their dedication to pushing through their mistakes that lead to genius (Dweck, 2014).

Traditionally in elementary mathematics education, mistakes were often treated as things to avoid and represented failed learning. Students were often made to feel they had low ability in math if they were making mistakes. In taking up assigned work, teachers would simply signal whether the student response was right or wrong. If an answer was discussed in detail, it was usually only the right answer that was examined. Teachers, parents, and students need to view mistakes not as learning failures but as opportunities to learn. It is through mistakes that students have the chance to build their brains through new learning (Boaler, 2013; Dweck, 2014). It is powerful for students to have a chance to analyze their mistakes to find out why they were wrong and how to change their thinking to find the correct answer for that question.

Teachers need to provide more open and challenging tasks that give students the opportunity to explore mathematical concepts and procedures and to learn through their mistakes. When students realize that mistakes are opportunities for learning, they will be more likely to embrace more challenging tasks that may cause them to make mistakes requiring more perseverance and effort. Students quickly perceive what their teachers in math class value. Teachers need to avoid praising students for answering questions that

do not require much thinking or effort but rather offer praise for embracing a challenging question, hard work, perseverance, and learning from mistakes (Dweck, 2014).

A growth mindset for elementary teachers and their students is a vital part of a comprehensive mathematics pedagogy. It begins with educating teachers about growth mindset and learning. They will also need time to relearn the mathematics content from a growth mindset perspective to begin to change their beliefs about their own ability to learn and do mathematics. In the classroom, teachers need to talk to their students about growth mindset and how learning comes from effort and perseverance. Students need to know that mistakes are opportunities for learning and challenging tasks often provide the best environment for learning new ideas. Teachers need to be clear about what they value in the mathematics classroom because the students are always watching and listening.

If students have a growth mindset in mathematics, they will be more willing to spend time on practice questions to improve because they believe their efforts will make a difference in their learning. The elementary mathematics teacher needs to provide practice questions with a focused purpose to address the specific learning needs of their students.

Purposeful practice. For many teachers, parents, and students, the word practice in math class often meant homework. Elementary mathematics teachers assigned mathematics homework for students to practice what they had hopefully learned in class. Parents often welcomed the homework not only for the additional math practice but to help their children learn the value of hard work, time management, and responsibility. There is some evidence that homework completion can have a positive effect on student self-efficacy and self-regulation (Bembenutty & Zimmerman, 2003; Kitsantas &

Zimmerman, 2009) which will serve students well in later academic endeavours.

However, many studies have found that homework completion is not associated with higher academic achievement in elementary school (Cooper, Lindsay, Nye, & Greathouse, 1998; Kitsantas et al., 2011). This finding could be explained by the experiences shared by many students who, after not understanding the mathematics in class, had this misunderstanding reinforced when they were not able to figure out the correct answers to homework questions causing frustration. These experiences could contribute to a fixed mindset and negative attitudes towards mathematics (Boaler, 2013).

Keith, Diamond-Hallam, and Fine (2004) found that students completing practice questions or homework in class had a positive effect on student achievement; however, there was no effect on achievement for students completing the homework outside of class. Completing practice questions in-class allows students to ask questions of their peers and teacher in order to clarify misunderstandings and consolidate their learning. Besides improving student achievement, these in class practice experiences may also develop student growth mindset in mathematics as students see the value of practice in terms of understanding and becoming better at mathematics. The majority of elementary mathematical practice should occur in the classroom especially for recently learned material where student understanding may be tenuous.

Any homework given to students should be given thoughtfully in regards to purpose. While there is little evidence of increased student achievement in mathematics for homework given for practice or preparation purposes, there is some evidence of increased student learning for homework that is designed to extend existing

understanding (Rosário et al., 2015). When designing student practice work, the first instructional decision for mathematics teachers should be the purpose of that practice.

Traditionally, in many elementary mathematics classrooms, students were given the same practice questions that were often of a closed type requiring the recall of a procedure or term demonstrating memory recall. In a study of third grade mathematics homework 68% of the practice questions were classified as low level remembering type items (Bedford, 2014). Students who had already memorized the math being practised quickly became bored with the practice while students who had memory recall issues would become frustrated with repeatedly getting incorrect answers. These types of practice questions not only do not improve student achievement but also negatively affect student mindsets (Boaler, 2013). There needs to be a shift in the design of practice questions in elementary mathematics that will increase student achievement and encourage a growth mindset.

In order to design effective practice assignments for students, teachers need to possess conceptual and procedural knowledge of the mathematics content and accurate knowledge of the level of understanding and skills their students possess in regards to the topic they are teaching (Epstein, & Van Voorhis, 2001). Students experience different stages of development within a mathematics topic in regards to pace and their understanding of ideas, models, and strategies. In order to provide effective practice, teachers need to provide differentiated practice opportunities that meet the student needs according to their stage of development. A number of authors have supported elementary teachers in Ontario by providing mathematical developmental landscapes and maps to help identify where students are within a mathematical topic (Beatty, & Bruce, 2012;

Fosnot & Dolk, 2001; Lawson, 2015; Small, 2005). Teachers will need time to study and become familiar with the mathematical content and stages of student development in order to incorporate this knowledge into practice question design. By providing students with developmentally appropriate practice experiences, there is a higher likelihood of improved achievement and this success will in turn support a growth mindset in both students and teachers.

After being introduced to new mathematical concepts, models, skills, and procedures, students will need practice to consolidate their learning and to use new knowledge and strategies in different contexts. The amount and type of practice should vary according to student need and the mathematical topic being studied. In order to provide purposeful practice, educators need to have sufficient knowledge of both the mathematics content they teach and how students acquire and develop that knowledge (Ball et al., 2005).

A comprehensive mathematics pedagogy should include student experiences of (a) learning through problem solving, (b) acquiring procedural fluency through conceptual understanding, (c) developing a growth mindset, and (d) consolidating learning through purposeful practice. This pedagogy needs to be a nonnegotiable standard for all mathematics educators at the school, board, and provincial level.

Professional Learning

There is no greater impact on student learning and achievement than the daily interactions of teachers with their students (Darling-Hammond, 2000; Hattie, 2008). During the past 6 years, in the Ontario elementary mathematics context, instructional practices have resulted in decreasing student achievement in elementary mathematics

(EQAO, 2016). This era of decline in Ontario, coincided with elementary mathematics professional learning and resources, focused on teaching and learning mathematics through problem solving. If this professional learning was introducing teachers to a more effective way to teach elementary mathematics, why was there a decline in student achievement? There are a significant number of people inside and outside of the educational community who believe this new way of teaching mathematics shared with teachers is the cause of the decline (Csanady, 2016; Stokke, 2015). This belief suggests that the majority of elementary teachers in Ontario have changed their practice and implemented this new way of teaching. Based on observations and conversations with hundreds of elementary mathematics teachers during this time period, I contend that this is not the case in the majority of Ontario mathematics classrooms.

In my opinion, the decline in student achievement in elementary mathematics is the result of insufficient and, or, the incorrect kind of professional learning opportunities for educators, resulting in instructional practices, which considered as a collective, could best be described as confused. On one end of the spectrum are elementary mathematics teachers who still use traditional practices emphasizing direct instruction and memorization; on the other end, are teachers who have changed to teaching mathematics using a more comprehensive pedagogy. The majority of elementary mathematics teachers in Ontario are somewhere in between these two ends of the spectrum, using parts of traditional and comprehensive pedagogies or trying to teach in new ways without sufficient understanding or experiences. For many elementary mathematics students, this instructional mixture often leads to confusion as teaching methods and messages change from year to year often resulting in frustration and decreased achievement. In order to

clear up this collective instructional confusion in mathematics, changes to professional learning based on research and past experiences will be required.

As an elementary mathematics education consultant, I am often asked how I know if professional learning initiatives for teachers have been successful. I agree with the description of learning as the process through which experience causes permanent change in knowledge or behaviour (Woolfolk, Winne, & Perry, 2012). However, in order to have a positive impact for all students, the permanent change of one teacher in a school is not enough. It needs to include all the teachers of mathematics in the school, board, and province. The goal of professional learning in the Ontario elementary mathematics education context should be a collective change in teaching practice to reflect a comprehensive mathematics pedagogy. What professional learning elements will be required to cause this collective, permanent change?

A shared vision. In order to spark initial interest, effective professional learning needs to begin with a shared vision consisting of solutions to instructional issues identified by educators (Hord, 2009; Timperley, Wilson, Barrar, & Fung, 2008). In order for professional learning to occur there needs to be a desire on behalf of the participants to learn. Regardless of the initial participant interest level in professional learning, more successful outcomes occur when reasons for participation are connected to student needs (Timperly et al., 2008). In the Ontario mathematics context, the vision of comprehensive mathematics should not be presented as top-down, mandatory instructions to be followed but rather shared with educators in response to instructional questions and challenges put forward by teachers of mathematics. Teachers will need time to change their beliefs (Polly et al., 2014). Teachers and administrators will need to consider and revisit

elements of comprehensive mathematics especially if they challenge past instructional practices and beliefs and when they encounter roadblocks during implementation.

Opportunities for discussion need to be provided for educators to share their thoughts, questions, and challenges about comprehensive mathematics if this is to truly be a shared vision.

Upon initial introduction of the vision of comprehensive mathematics, it will be important to share that vision at the school, board, and provincial level as a collective goal. In order to promote consistent instruction of comprehensive mathematics in the classroom, this vision must become a nonnegotiable part of the culture of teaching elementary mathematics in every school in Ontario. This change in culture will depend on the collective efforts of all educational stakeholders in the province beginning with our leaders.

When teachers believe the principal supports professional learning, it positively affects attitudes and outcome (Heck, Banilower, Weiss, & Rosenberg, 2008; Robinson, Hohepa, & Lloyd, 2007). I also contend that when superintendents actively support professional learning, it will have similar positive effects on principal attitudes. In my experience as an educational consultant, the most powerful type of principal and superintendent support is active participation in learning. When teachers see their principal and superintendent sitting with them, not necessarily as the knowledgeable leaders but as co-learners, it emphasizes the value of learning about the shared vision while building new relationship dynamics as equals. The support of all educational leaders for the shared vision of comprehensive mathematics will be vital in transforming instructional practice.

Once the vision of comprehensive mathematics has been established, it should become a collective touchstone for educators and schools to refer to in order to determine professional learning needs and next steps. The effectiveness of that professional learning will depend upon the inclusion of components highlighted in the research.

Patience and time. A permanent change in knowledge and practice at the classroom, school, board, and provincial level will take time. The teaching of mathematics is a complex endeavour that requires a depth of knowledge of not only the mathematical content but also the ways in which students acquire that content, how to deal with misconceptions that may arise, and which interventions will support them (Ball et al., 2005). For most educators, moving to a comprehensive mathematics approach will require relearning the math content as well as learning about new pedagogical approaches for teaching mathematics.

In Ontario, professors at faculties of education report elementary teacher candidates experiencing difficulty answering questions and tests containing numeracy concepts they will be expected to teach. At one faculty, one in three teacher candidates fail to pass a test containing numeracy concepts such as multiplication, division, and fractions (Brown, 2016). This underscores the need for a change of mathematics instruction in Ontario as the majority of these teacher candidates were instructed in a traditional, direct instruction model often emphasizing memorization of rules and procedures. Educators will need time to re-learn the concepts they teach so they move beyond memorized rules and procedures to understand underlying concepts through new models and procedures and shift to a different way of viewing mathematics as a subject to be understood rather than memorized. This time will be well spent, as many

elementary mathematics teachers lack a growth mindset when it comes to math due to negative experiences in their own schooling or a lack of understanding. In my experience during professional learning focused on math content, many elementary mathematics teachers have expressed excitement in understanding math concepts for the first time and as a result experienced a change in their beliefs about learning and teaching mathematics. This new learning will take time to be consolidated and may happen simultaneously with the students they are teaching.

Even if teachers change their beliefs it is not necessarily enough to change practice to reflect those beliefs (Vacc & Bright, 1999). In elementary mathematics professional learning with hundreds of teachers, I have collected qualitative survey data in which the vast majority of participants reported a change in beliefs regarding the teaching of mathematics and an intention to change their practice as a result of the professional learning. Upon returning to the classroom, very few teachers reported a permanent change in practice despite a stated change in beliefs. The majority of elementary mathematics teachers are generalists teaching up to seven different subjects, each requiring time for planning. Many participants began to change their instruction in mathematics but found it too time-consuming and encountered too many challenges in implementing this new type of instruction; therefore, they returned to traditional instruction that took less time to plan. Teachers need time to not only relearn mathematics themselves and change their beliefs but also to relearn how to teach mathematics, have opportunities to try it, and then time to ask questions, reflect, and try again.

In order to have a significant impact on teacher practice to increase student achievement, educators will need a substantial amount of time for professional learning. In some cases, an average of 49 hours of professional learning was needed to have a moderate effect on student achievement (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007).

Professional learning needs to be focused according to teacher needs to address both mathematics content and the content concerned with teaching mathematics. Schools, boards, and the province will need to be patient, as it will take years for this amount of professional learning to reach all elementary educators. Providing adequate time for professional learning is important but how that time is spent will be vital.

Focus on student needs. In the past, many elementary mathematics professional learning sessions were held in large rooms with the same content for all educators regardless of their experience or differing needs. These educators were presented with knowledge in the hope that the absorption of this knowledge would change their practice. This was most often not the case as there was often a disconnect between the theory and putting it into practice. What made sense and looked easy during professional learning sessions became much messier and more difficult in the reality of a classroom of individual students with a variety of learning needs. Instructional roadblocks quickly overwhelmed many teachers with this fragile, new knowledge and most returned to the way they had been teaching.

The work of professional learning needs to be grounded with a focus on student work. (Katz & Dack, 2013; Timperley, & Alton-Lee, 2008). If we believe professional learning has occurred when there is a permanent change in practice, would it not make

more sense if the learning were more closely connected to that practice? All of the teachers I have worked with, regardless of subject area, have had the same professional learning goal or need, to improve student learning. If we want to engage all educators in professional learning, we need to focus that learning on the needs of their students in regards to comprehensive mathematics. Instead of a top-down approach of presenting the components of comprehensive mathematics as knowledge blocks to be memorized, professional learning should start with the identification of a student learning need in mathematics. The student learning need determines a learning need for the teacher. The teacher learning focus within comprehensive mathematics and, or, mathematical content will come from the investigation of what that teacher needs to learn in order to support what his or her students need to learn (Katz & Dack, 2013).

Educational leaders also need a learning focus based on the needs of the teachers. Principals, superintendents, coaches, and consultants need to ask what they need to learn to support teacher learning that in turn will support student learning. Superintendents, school principals, and vice-principals may not need to learn as much about the mathematical content or comprehensive mathematics as the teachers but they should learn enough to participate in instructional conversations and recognize recommended instructional practices through observation. School leaders will need to focus their learning needs on their teachers' learning needs. In some cases, it may be learning how to create a culture of learning in a school where teachers have had negative experiences in the past and are now reluctant to engage in professional learning. Superintendents will face a similar process in determining their learning needs to support the learning of their school leaders. Consultant staff may face the biggest challenges, as all of these groups in

a sense are their students. They will need to anticipate the learning needs of all participants and be able to shift according to a variety of needs and audiences.

In order to promote permanent changes in teacher practice, professional learning about comprehensive mathematics and mathematical content must be based on student learning needs. The focus on student needs will encourage teachers not only to participate in professional learning about comprehensive mathematics, but also to change practice because traditional instruction has not worked for these students. Educational leadership must play a role by identifying the needs of their students in order to support teachers in their learning. Successful professional learning will promote changes in practice; however, these changes must be accompanied with the understanding of the theory or knowledge behind them.

Knowing and doing. In order to improve student learning and achievement, teachers need to combine knowledge of the math content in the curriculum with effective pedagogical knowledge in order to respond to student needs. In order to determine those needs, teachers need the content knowledge to assess student progress within the curriculum and the pedagogical knowledge to determine effective next steps in instruction (Hammerness, et al., 2005; Timperly et al., 2008). Effective professional learning, therefore, needs to integrate content, pedagogical and assessment knowledge with opportunities to apply this knowledge in the classroom and time to reflect, share experiences, and ask questions to refine practice. If professional learning does not include this integration, educators could return to the classroom with new knowledge of mathematical content but no knowledge of effective ways to share that knowledge with their students. Alternatively, educators could return to the classroom with new

instructional techniques without knowing the mathematical content. “Practice is the visible face of understanding, and changing practices means changing understanding. And if a practice changes without the underlying understanding there is no reason to expect it to have the desired effect on student achievement” (Katz & Dack, 2013, p. 28).

In the Ontario elementary mathematics context, I suggest that insufficient professional learning opportunities in the past have resulted in collective instructional confusion caused by insufficient content knowledge, pedagogical knowledge, and practice opportunities.

In some cases, teachers have adopted practices without sufficient pedagogical knowledge. For example, the three-part problem solving lesson has been implemented in many mathematics classrooms; however, in some cases, without an understanding of the pedagogical purpose of each part. The three-part lesson consists of introducing the problem, students working on the problem, and the sharing of student solutions to consolidate learning. In some classrooms, well-meaning teachers would preteach concepts or procedures and then present the question, essentially taking the problem solving out of the lesson by telling the students how to do it first. In other classrooms, little or no time was used for the third part of the lesson to discuss student solutions, explore different ways of thinking, examine errors, and summarize the learning. I believe the omission of the third part of the lesson in many classrooms contributed to the label of discovery math in the Ontario media.

In other cases, teachers may have insufficient math content knowledge. For example, it is very difficult to have an effective problem-solving lesson unless you have a deep understanding of the mathematical content and how students learn that content. In

some cases the third part of the lesson may be glossed over or skipped because the teacher is not sure of the mathematical purpose of the lesson or how to adjust the purpose to match the student thinking in the solutions that were produced. Teachers of elementary mathematics today are expected to have a greater depth and breadth of the mathematical content they teach than their colleagues did in years past. For example, traditional multiplication instruction usually consisted of the memorization of times tables, flash cards and worksheets for practice, memorization of the standard algorithm, worksheets for practice, and then word problems. This instruction often emphasized memorization of facts and procedures and not understanding the concept and underlying principles. Thanks to educational research (Fosnot, & Dolk, 2001; Small, 2005; Van de Walle et al., 2004), much has been learned about elementary mathematics concepts and more importantly how students acquire them. When teaching multiplication today, teachers have access to developmental maps outlining important ideas, models, and strategies within the topic of multiplication. This detailed content knowledge for teachers allows them to instruct students in a way that will promote the understanding of multiplication while supporting the learning of basic facts and effective strategies for multiplying numbers.

Educators will need time to not only re-learn the elementary mathematical content themselves but also learn the new pedagogy of comprehensive mathematics and how to combine the content and pedagogy most effectively in the classroom. Professional learning will require numerous cycles of learning where time is spent exploring the theory and gaining new knowledge followed by a return to the math classroom to apply it and gather observations and instructional questions. For complex learning such as this,

teachers will typically take 1 to 2 years to understand how existing beliefs and practices are different from those being promoted, to build the required pedagogical content knowledge, and to change practice (Timperly et al., 2008). In order to support the complex learning of both the mathematical and pedagogical content, a knowledgeable other with expertise in these areas will be required.

The knowledgeable other. To improve the outcomes of professional learning, the inclusion of a knowledgeable other from outside the group of participating teachers will be necessary to challenge past beliefs and practices, introduce new knowledge, and focus and support educator learning to improve student learning (Cordingley, 2015; Cordingley, Bell, Isham, Evans, & Firth, 2007; Timperly et al., 2008). This knowledgeable other could be an administrator from within the school or a consultant or researcher from outside the school. When selecting a knowledgeable other, the position of this person is not important; however, the expertise they possess will be. This expertise needs to include not only the math content knowledge and pedagogical knowledge but also the knowledge of successful elements of professional learning such as shared vision, patience, and time, focusing on student needs and integrating theory with practice.

In recent years, many Ontario school boards have decentralized professional learning. Instead of having educators come to board offices or ballrooms for large central professional learning sessions, the learning has been moved back to the school level in what is often referred to as site-based learning or professional learning communities (PLCs). The idea was to move the learning closer to the classroom and that teachers would be able to learn from each other or learn together by digging into instructional problems. The intent was for school educators to work together and, as a result, change

practice and improve student achievement. The results in the research have not supported these conclusions (Katz & Dack, 2013; Supovitz, 2006). The focus of the PLC was often on the working together with the assumption that this action would produce positive learning results regardless of the activity.

In some cases, the PLC became a smaller version of traditional professional learning where participants sit and listen to a speaker or watch a video to receive knowledge with little focus on the classroom practice and student needs. In other cases, educators may have watched a model classroom in action and took notes only to return to their classrooms to copy what they had seen without understanding the reasons for what they were doing. Even in school sites where student work was being discussed, participants became victims of confirmation bias or the idea that when people believe in something they only look for things that confirm that belief not things that challenge it (Katz & Dack, 2013). In the context of elementary mathematics professional learning, this often meant poor instructional practices were reinforced because of a misplaced collective belief.

The fault is not with the idea of site based learning and PLCs. I believe in the potential of site based learning because it can be tailored to the needs of the individual school and classrooms are available to provide the possibility of observing theory being put into practice with students the teacher participants actually teach. Regardless of the type of professional learning, a knowledgeable other will be required to challenge confirmation bias, ensure the learning is focused on student needs, and include opportunities for practice between sessions.

In a study on leadership and school outcomes (Robinson et al., 2007), different leadership dimensions were identified and tested against student achievement. The dimension that clearly had the largest effect size was promoting and participating in teacher development. This dimension was highlighted earlier in this discussion in regards to principals but I contend that it also holds true for the knowledgeable other that is leading the learning. As a leader, the knowledgeable other must be willing to dig in and do the work of learning beside the teachers and administrators. Some of the best professional learning experiences I recall involved the collective planning of a mathematics lesson by myself and four to five teachers and then going in to teach and observe the lesson. On some occasions, I did the teaching and things did not go according to plan. The teachers appreciated the fact that the knowledgeable other did not know everything and that sometimes the theory does not work. It created a different dynamic when teachers saw the so-called expert was willing to teach and made mistakes. After the lesson, we had a chuckle and proceeded to try to find out what had happened during the lesson and why it happened that way. Learning is messy and theory does not always seem to work in the elementary mathematics classroom. This emphasizes the importance of always combining theory with practice and having a knowledgeable other who is willing to walk the talk.

In order to begin a collective, permanent change in instructional practice to improve student achievement in elementary mathematics classrooms in Ontario, high quality professional learning must be provided. This professional learning should begin with the shared vision of comprehensive mathematics arising from the student needs identified by teachers. This shared vision needs to become a nonnegotiable touchstone

embedded in the elementary school mathematics culture. Professional learning needs to involve a knowledgeable other who will weave theory and practice, content and pedagogy throughout the sessions based on the needs of the teachers and their students. All educational leaders need to participate in this learning to signify its importance and to demonstrate a willingness to work and learn shoulder to shoulder with teachers.

Effective Teacher Assessment and Feedback

Let us assume the province of Ontario adopted all of the suggestions for improving student achievement in mathematics in this discussion up to this point. How would we know if the adoption of comprehensive mathematics and suggestions for professional learning were actually changing teacher practice and increasing student achievement? How would teachers receive support for the many instructional questions and roadblocks that arise when implementing theory into practice? The answer to both of these questions can be found in an instructional practice that has been highly recommended for students yet seldom used with teachers, effective feedback through formative assessment (Black, & Wiliam, 2009; Hattie, & Timperley, 2007).

In the past, in most cases, two tools have been used to measure the impact of professional learning on elementary mathematics instruction in Ontario, qualitative survey data and EQAO assessment data from grades 3 and 6. As highlighted earlier in this discussion, in my experience, qualitative survey data were often unreliable. While some participants shared an intention to change practice in the future, others reported changes in practice made during the professional development. Without observation, there was no way to verify whether these changes occurred. For those teachers who did

change practice, there was often a return to traditional practice due to a lack of support for instructional issues that arose.

EQAO data have often been used to make school and board decisions regarding professional learning and instructional emphasis in Ontario. It has also been used as a measure of the effectiveness or impact of professional learning on student achievement. The use of EQAO test scores to make impactful decisions and draw conclusions about professional learning are not appropriate (Crundwell, 2017). Beyond the lingering concerns with the reliability (Wolfe, Childs, & Elgie, 2004) and validity (Crundwell, 2017) of the EQAO assessments, the greatest concern may lie with the misinterpretation of EQAO scores. For example, the increase of grade 3 math scores for the same teacher from one year to the next could be due to the differences in the cohort of students being tested and not a change in pedagogy. Even if one were to assume a rise in a teacher's EQAO mathematics scores from one year to the next was due to a change in teaching practice, the students' scores would not provide any information about the type of math instruction the teacher was using. While historical EQAO data can provide some information regarding trends in student achievement in mathematics over time, it should not be used to measure the impact of professional learning. If the intended result of professional learning is a permanent change in teacher practice to improve student achievement, then instructional practice needs to be observed and assessed. Most importantly, teachers need to receive feedback on their practice in order to support and promote instructional change.

In their impactful article written almost 20 years ago, *Inside the Black Box: Raising Standards Through Classroom Assessment*, Black and Wiliam (1998) posit that

many system leaders treat teaching as a black box. Students, teachers, curriculum, high expectations, and professional learning are some of the inputs that enter the black box with the hope that coming out of the box will be confident, satisfied teachers, knowledgeable students with growth mindsets, and increasing student achievement results. These authors argue that little attention is ever given to what is happening inside the box, the actual teaching and learning. Historically, professional learning consisted of presenting knowledge in workshops and then teachers were sent back to the classrooms to figure out how to implement it on their own. How will we know the impact of different inputs on learning unless we observe what is going on inside the box? Black and Wiliam (1998) focus their study on the inside of the box, specifically on the importance of the formative assessment of student work in effective teaching. Hundreds of articles relating to and building on the work of Black and Wiliam (1998) support the importance of formative assessment in teaching and learning (Hattie, J., 2008). As a result, formative assessment also became a large focus for professional learning and a popular term and adopted instructional tool in schools throughout Ontario and the world.

In most cases, the leader in professional learning contexts imparts knowledge to the teacher in a ballroom or school library and then sends the teachers back to the black box, or classroom, to fend for themselves. This would be similar to an automotive mechanic teacher gathering a class of students to go over techniques and ideas for fixing a car and then asking them to go and start repairing cars without any guidance or support back in the shop. If formative assessment is so important to learning, then why is it absent from professional learning for teachers?

What is formative assessment? Heritage (2007) provides the following description of formative assessment:

Formative assessment is a systematic process to continuously gather evidence about learning. The data are used to identify a student's current level of learning and to adapt lessons to help the student reach the desired learning goal. In formative assessment, students are active participants with their teachers, sharing learning goals and understanding how their learning is progressing, what next steps they need to take, and how to take them. (p. 141)

Heritage proceeds to identify four elements of formative assessment: identifying gaps in learning, feedback, student involvement, and learning progressions. In identifying gaps in learning, the teacher needs to recognize if the gap between current student understanding and the goal is too large or too small and adjust the goal accordingly. For example, a leader may observe a teacher using a number string for multiplication instruction. The teacher is following the pedagogical steps for using a number string correctly; however, a lack of content knowledge regarding the distributive property is negatively impacting the class discussion and learning. The leader needs to recognize the gap in learning as multiplication content knowledge for teaching and make plans to adjust a learning goal for this teacher to fill the gap.

Feedback involves both teacher and students and occurs on different levels. It begins with students demonstrating an understanding of what they know. In the example above, the leader receives feedback about what the teacher knows about number strings and multiplication by observing the lesson. The leader in turn provides feedback that tells the teacher where they are in terms of the learning goal and specific steps of how to

move forward. In this example, the leader may highlight the correct pedagogy used during the number string and then focus on the mathematical purpose of the string to raise the need of deepening content knowledge of multiplication in order to connect student solutions and highlight mathematical learning during teaching. The leader should provide next steps such as providing resources to deepen knowledge or a brief dialogue and discussion concerning the distributive property in multiplication and its place in student learning. The teacher may come back to the leader with questions and ideas that provide further feedback to the leader and the cycle begins again. Feedback is one of the most powerful influences on learning (Hattie & Timperley, 2007) and needs to become a part of professional learning for teachers.

In the context of Ontario, the large number of elementary mathematics teachers will necessitate the use of self and peer assessment in order to support one another in providing formative assessment and feedback. The knowledgeable other or leader will not always be there; therefore, it will be important for teachers to assess their own practice or to rely on feedback from their peers or a school principal. In the absence of a knowledgeable other or leader, it will be important for the group to refer to a learning trajectory or progression that not only provides general or larger learning goals but also smaller check points that contribute to the larger goal.

In the Ontario elementary mathematics context, the larger learning goals for educators are concerned with pedagogy and curricular mathematical content. Comprehensive mathematics is a general pedagogy goal divided into four component goals of (a) teaching through problem solving, (b) developing procedural fluency through conceptual understanding, (c) growth mindset, and (d) purposeful practice. Each of these

component goals would consist of smaller goals that contribute to achieving the component goal. In our example, the use of number strings would be a smaller goal contributing to developing procedural fluency. While working on the pedagogical goal, there will also be a mathematical content goal generally defined by the curriculum. In the number string example, the content being addressed would be found under the curriculum strand of number sense within the curriculum topic of operational sense and addressing the specific curriculum expectation of multiplying whole numbers using a variety of mental strategies. This specific number string supports an underlying goal of using the distributive property. In order for formative assessment and feedback to continue without the presence of a knowledgeable other, it will be vital to provide teachers with learning trajectories that not only provide general goals and curriculum expectations but the cascading underlying goals of both the pedagogy and mathematical content.

Effective formative assessment and feedback will play a foundational role in initiating, sustaining, and deepening professional learning for elementary mathematics teachers in order to change instructional practice to improve student achievement. To provide effective formative assessment and feedback, professional learning leaders, knowledgeable others, principals, and teachers will need math content knowledge, pedagogical knowledge, knowledge of previous student learning, and knowledge of assessment. It will take time for all educational stakeholders to acquire this knowledge. In order to promote and support effective formative assessment in the area of elementary mathematics, new assessment tools need to be developed especially for Ontario principals and vice principals who perform the bulk of teacher assessments.

Moving from assessment of teaching to assessment for teaching. Currently in Ontario, the process and requirements for the evaluation of elementary teachers are outlined in the *Teacher Performance Appraisal System* (OME, 2017b). A school principal or vice principal is required to evaluate each experienced elementary teacher every 5 years using a summative report form provided by the government (OME, 2010). During this evaluation, there is some surface level discussion between the administrator and teacher about pedagogy and content guided by general questions in the evaluation form. In my experience, these evaluations rarely impact teaching practice because the primary purpose of the evaluation is summative, to provide a satisfactory or unsatisfactory rating. Summative teacher evaluations for the purposes of certification or re-certification are necessary; however, different assessment tools will be required for the purpose of formative assessment and changing instructional practice in elementary mathematics.

There are a variety of studies that focus on ways to assess teacher effectiveness. In my review of the literature, one principle of teacher evaluation kept appearing regardless of whether the evaluation purpose was summative or formative. That common principle was to collect evidence from a variety of sources (Berk, 2005; Cantrell & Kane, 2013; Fink, 1999; Reddy et al., 2013). Evidence should be collected from teacher self-evaluation data (e.g., portfolios, audio and video tapes, journals), student growth data (e.g., pre and post test results), student perception data (e.g., questionnaires, focus groups) and outside observer data (e.g., peer or administrator observations). The inclusion of the teacher, students, and qualified knowledgeable others from outside the classroom should provide a more balanced evaluation then relying on one source. The selection of a source or combination of sources should rely on the purpose of the

assessment or, sometimes, the results from other assessment sources. For example, as a result of decreasing student assessment data and questions arising from a teacher's self assessment data, a teacher may value peer or administrator observation to provide feedback.

The literature includes some suggestions and ideas for increasing the reliability and validity of assessment sources. In the case of peer or administrator observations, there is evidence that these observations were more reliable if there were multiple observations done by multiple observers who were trained and assessed for accuracy before observing (Ho & Kane, 2013). The observers included a school administrator, peers, and outside school administration. The observers were trained using a common assessment framework or tool to record observations of videotaped lessons. These observations were compared to the benchmark observations for training. There are a number of existing observation tools or frameworks for mathematics teaching that include training materials (Danielson, 1996; Hill, 2010). These frameworks could provide excellent starting points for Ontario school boards interested in providing reliable formative assessment and feedback for teachers of elementary mathematics. Over time, the province, board, or school staff could create their own observational tools tailored to their instructional focus and recent professional learning.

Formative assessment and providing effective feedback have been highlighted as effective ways to improve student learning in the literature and through the OME. In the assessment, evaluation and reporting policy document titled *Growing Success: Assessment, Evaluation, and Reporting in Ontario Schools* (OME, 2010b), an entire chapter is dedicated to assessment for learning in which formative assessment and

feedback are emphasized and set out as policy for teachers in grades 1 to 12. Yet, when it comes to professional learning for teachers, there is an absence of formative assessment and feedback. In order to permanently change instructional practice in Ontario elementary mathematics classrooms, school boards need to provide support where it matters most, in the classroom, where the teaching and learning take place. Formative assessment and effective feedback will provide teachers with valuable information and support the difficult task of implementing a new pedagogy.

Chapter Summary

If we teach who we are (Palmer, 1997), then I would argue that we write who we are. In reviewing this chapter, it is clear that my personal experiences as a math student, teacher, and consultant impacted my choices for the research I explored and ultimately chose to highlight in this portfolio. Years of exploring research have changed how I think, what I believe, and how I do my job; in essence it has changed who I am.

The research referenced in the literature review is not exhaustive but represents what I believe are key elements required to improve elementary students mathematics achievement in the province of Ontario. A comprehensive mathematics pedagogy, high quality professional learning, and providing teachers with effective formative assessment and feedback would make an excellent start.

CHAPTER THREE: REFLECTION ON THE COLLECTION OF ARTIFACTS

I have selected a number of artifacts to share that were created during my time as a Master of Education student. I will share my reflections on these artifacts and their potential contributions and impact on improving elementary mathematics education in Ontario.

Process of Artifact Selection

The artifacts provided in this portfolio support the use of a comprehensive mathematics pedagogy, professional development for educators, and effective teacher assessment and feedback in order to improve elementary student achievement in mathematics in Ontario. The artifacts provide additional background information and practical examples that may be useful to educators exploring ways to improve elementary mathematics education.

These artifacts are organized by the order in which the topic appeared in this portfolio. Most of these artifacts were produced as course assignments, while others were created during my role as an elementary consultant. A description of each artifact is provided and they are included as Appendices at the end of the portfolio.

Artifacts

In this section, I will provide a list of the artifacts, identified by number, as well as a brief description of the contents of each artifact. All actual artifacts can be found in the Appendices in the same order as the list below.

Curriculum Vitae: Ed Enns

This artifact has been included to provide a more detailed description of my educational, professional and leadership experiences to date. These experiences have all

contributed to my beliefs about mathematics education and professional learning and can be reviewed in Appendix A.

Essay: What's the Problem? An Exploration of Teaching Mathematics Through Problem Solving

This artifact was created as partial fulfillment of the Masters of Education Program at Brock University in the *Mathematics in the Curriculum* (EDUC 5P55) course in July of 2013. The essay explores teaching mathematics through problem solving, a major element of comprehensive mathematics, and can be found in Appendix B.

As a teacher and consultant, I recognized the confusion surrounding the pedagogy known as teaching through problem solving inside and outside of the educational community. This confusion caused a limited or misguided use of the pedagogy in classrooms while often being criticized as discovery math outside of the classroom by the press. In this essay, I attempt to clarify the confusion by answering an important question: What does learning or teaching through problem solving really mean?

A review of a variety of definitions concerning teaching through problem solving is presented. A historical perspective of teaching through problem solving in the elementary mathematics community is shared, leading to current understandings of the pedagogy and the recommended classroom environment.

PowerPoint Presentation: Parent Math Night

The creation of this artifact relied on the knowledge I had gained in my research of comprehensive mathematics during my Master of Education journey and my experiences in the elementary mathematics classroom as a teacher and consultant. This presentation was shared at a number of different parent math nights at individual schools as well as a meeting with representatives from all parent councils in the school board.

The original presentation was revised for inclusion in this portfolio to remove video clips and related questions, some content slides and graphics. In this presentation, beliefs about teaching and learning mathematics are examined, changes and reasons for changes in mathematics education are discussed, and ideas for parents to support their child's learning are shared. The revised presentation can be reviewed in Appendix C.

To begin this parent presentation, parents participate in an activity to uncover their own beliefs and feelings about the subject of mathematics. This leads to a discussion of where these feelings and beliefs come from, their experiences as students, and why math instruction needs to change. To illustrate how mathematics instruction is changing, parents are asked to do some math themselves. Recent standardized test results are shared and examined to further support the need for change. An explanation of comprehensive mathematics, a new pedagogy, and samples from the classroom are shared.

Inventory Results: Education Philosophy Inventory, Teaching Perspectives

Inventory for Ed Enns

This artifact was created as partial fulfillment of the Masters of Education Program at Brock University in the *Evaluating Teacher Effectiveness* (EDUC 5P87) course in January of 2014 and the *Adult Teaching and Learning* (EDUC 5P35) course in November of 2013. This artifact shares my results from two inventories, one concerned with educational philosophy and the other, with teaching perspectives (see Appendix D).

If we truly teach who we are, then it is important to understand who we are and what we believe about teaching and learning. In order to support a permanent change in teaching, there will need to be a change in beliefs. Too often in professional learning, educators are not provided time to share their current beliefs and discuss possible reasons to change those beliefs.

This artifact provides two examples of inventories that provide some insights into general teaching philosophies and perspectives that could begin a conversation about what we believe as teachers. Acknowledging and discussing beliefs about teaching and learning are foundational to professional learning.

PowerPoint Presentation: Listen to the Music, Representation of Learning

This artifact was created as partial fulfillment of the Masters of Education Program at Brock University in the *Adult Teaching and Learning* (EDUC 5P35) course in December of 2013. This presentation was created as a summary of my learning during the course and shares questions, quotes, and thoughts about adult learning supported by a variety of songs whose lyrics support the content being presented. Since the music audio cannot be shared in this portfolio, the original presentation was revised to include song titles and lyrics of the music that would be playing. The revised presentation can be reviewed in Appendix E.

The presentation begins by asking the audience to consider the role of music in sharing ideas and beliefs and in defining who we are. Following this, issues with current adult education are presented and ideas for change are suggested, including examining who we are as teachers. The presentation concludes with an imagining of what effective adult education could be.

PowerPoint Presentation: Collaborative Inquiry for Learning Mathematics

This artifact was created for the third and final session in a professional learning series for junior mathematics teachers from three different schools. Each school took turns hosting one of the sessions and had approximately four teachers and an administrator participating for a total of approximately 20 participants at each session. This presentation represents my attempt to bring some of the theory I had learned in my course work into my practice of professional learning.

The original presentation was revised for inclusion in this portfolio to remove video clips and related questions, some content slides and graphics. During this professional learning session, participants (a) continue their exploration of procedural fluency through the use of number strings, (b) are introduced to the components of comprehensive mathematics, (c) begin to explore purposeful practice, and (d) participate in a lesson study. The revised presentation can be reviewed in Appendix F.

This professional learning series attempts to honor much of what I have learned about effective professional learning. The components of the professional learning series begin with a sharing and discussion of beliefs and each session includes putting theory into practice by planning, teaching, observing, and reflecting on a math lesson in the participants' classrooms. The teachers have the opportunity to share reflections and feedback on the observed lesson in order for the collective group to generate suggestions for improvement. The professional learning theory in each session is customized according to the needs of the participating teachers.

PowerPoint Presentation: Evaluating Teaching

This artifact was created as partial fulfillment of the Masters of Education Program at Brock University in the *Evaluating Teaching Effectiveness* (EDUC 5P87) course in February of 2014. In this assignment, we were asked to evaluate a video clip of teaching using an existing teacher evaluation framework including teaching strengths, areas for improvement, and impact on student learning. We were also asked to comment on the limitations of the evaluation tool we used and to provide suggestions for improvements. I shared my assignment with my classmates during one of our classes in a short PowerPoint presentation that can be found in Appendix G.

In this presentation, I begin by sharing specific information about the elementary mathematics lesson I observed on YouTube and by identifying the tool I used to evaluate the video clip. Specific observations of teacher strengths and areas for improvement are discussed and impacts on student learning are provided. The presentation concludes with the limitations of this evaluation tool I experienced when using it to evaluate an elementary mathematics lesson and the adaptations I would make to improve it.

Essay: Evaluating Who We Are

This artifact was created as partial fulfillment of the Masters of Education Program at Brock University in the *Evaluating Teaching Effectiveness* (EDUC 5P87) course in March of 2014. In this essay, I explore the question of whether the examination of teaching and learning philosophies should be a fundamental part of the teacher evaluation process for both the evaluator and the teacher being evaluated. This question is explored by examining the suggested changes I made to an existing evaluation tool through the lens of my beliefs about teaching and learning. This essay can be reviewed in Appendix H.

In the essay, I share my own educational philosophies through my results from two teaching inventories. I examine how these philosophies affect my believed purpose for the evaluation of teachers and in turn how these beliefs impacted my edits of the Ontario teacher appraisal tool. I share experiences of using other elementary mathematics teacher evaluation tools and the importance of sharing similar teaching philosophies with those embedded in the evaluation tool. This underscored the need for a shared vision of comprehensive mathematics.

Chapter Summary

I appreciated the process of selecting artifacts for this portfolio. In reviewing my years of work and learning during my Master of Education program, I can see how the

knowledge I have gained through my courses has impacted my work in elementary education. As a result of these experiences, I feel I have developed a deeper and broader knowledge in the areas of mathematics education, adult learning, teacher assessment, and bringing theory to practice.

CHAPTER FOUR: SUMMARY, IMPLICATIONS, AND CONCLUSION

In this chapter, I present a summary of the portfolio, discuss interesting findings, and consider the implications of this portfolio on theory and practice. I conclude with reflections on my personal learning through this process and how it will impact me in my role as an elementary mathematics education consultant.

Summary of the Portfolio

This portfolio was developed as part of the requirements for a Master of Education degree at Brock University, and to answer important questions that arose in my role as an elementary mathematics consultant while working with teachers and administrators. In an attempt to provide answers, I decided to develop a portfolio of learning that would include my personal and professional experiences, a review of the literature, and a selection of artifacts from my professional and course work while working towards my degree. These questions helped to organize this portfolio, focus my search of the literature, and support the selection of the artifacts.

How Should We Teach Mathematics?

Both the media and Ontario elementary mathematics educators have asked this question largely in response to recent declining EQAO standardized test scores in grades 3 and 6 mathematics (EQAO, 2016). This decline coincided with the introduction of a new elementary mathematics pedagogy that emphasized teaching through problem solving (TTPS). The media reported the decline in results was caused by this new approach often labelled as discovery math (Csanady, 2016; Stokke, 2017). This new pedagogy was criticized for a lack of emphasis on basic facts and procedures and a lack of direct instruction.

For most elementary mathematics educators, TTPS was a revolutionary new approach that took the traditional model of teaching mathematics and turned it upside down. Due to the degree and complexity of this change in pedagogy, TTPS became the main focus for the majority of elementary mathematics professionals learning in Ontario. The singular emphasis of TTPS had unintended consequences in many elementary mathematics classrooms. Many educators came away believing basic facts and procedures should be deemphasized or no longer taught and that the role of practice should be greatly diminished. Due to a lack of sufficient professional learning opportunities, the collective elementary mathematics pedagogy in Ontario would best be described as confused as some educators adopted the new pedagogy while others did not. Even amongst those teachers who were TTPS, there were different interpretations of what it meant. Many elementary mathematics teachers reported frustration as EQAO and classroom achievement results declined, the media criticized (Alphonso, 2016; Stokke 2017), and parents complained. Some teachers and administrators questioned the role of TTPS and wondered about the inclusion of other approaches including basic facts, practice, and direct instruction.

As a result of pressure from the media and the elementary mathematics community, I believe the OME (2017a) responded by publicly changing the focus for mathematics instruction to a more balanced or comprehensive approach (Ontario Ministry of Education, 2017) that is generally defined as including TTPS, direct instruction, and practice. What does a balanced or comprehensive approach to teaching mathematics really mean for the classroom teacher? What instructional components and considerations should be included?

I prefer term "comprehensive" (2017) mathematics instead of balanced, suggesting that all parts of the pedagogy are addressed without suggesting equality amongst the parts. In a comprehensive mathematics program, all instructional approaches are used; however, the amount of time and emphasis would vary according to the topic and the learning needs of the students.

Teaching through problem solving should be the foundational pedagogical approach in a comprehensive mathematics program. The majority of literature I reviewed supported the idea of teaching mathematics through a problem-solving approach as being more effective than direct instruction (Boaler, 2016; Fast & Hanks 2010; Lester, 2013; Rittle-Johnson & Star, 2007; Schmidt et al., 2007). It is important to note that TTPS is not discovery based learning where students are left to discover knowledge without the assistance of the teacher. TTPS allows students to develop their own thinking and ideas about important mathematical topics to be shared through worked examples that are analyzed and discussed by the class and teacher to clarify learning and misconceptions. TTPS should be the cornerstone of a comprehensive mathematics program.

An effective comprehensive mathematics program needs to include the development of procedural fluency that is built upon conceptual understanding and reasoning. Learning basic facts and procedures through number sense rather than isolated memorization will enable students to have better recall and a broader knowledge of calculations and procedures (Fuson et al., 2005, Kamii, 1985). Developing procedural fluency through conceptual understanding not only provides a foundation for number sense but also for a growth mindset (Dweck, 2006) in which students believe intelligence can be developed through persistence and practice.

The way in which people think about learning can generally be described in two ways. Those with a fixed mindset believe you are born with a certain amount of intelligence that will not change. Other individuals have a growth mindset and believe they can grow their intelligence over time (Blackwell et al., 2007; Dweck, 1999, 2007). Studies report the number of students with a fixed mindset in mathematics is higher than other subjects (Dweck, 2014). I believe this is a result of traditional mathematics instruction that often emphasized memorization without understanding. A growth mindset for elementary mathematics students is a vital part of a comprehensive mathematics pedagogy. In the classroom, students need to know that mistakes are opportunities for learning and challenging tasks provide ways to learn new ideas.

Traditionally, in many elementary mathematics classrooms, students were given the same practice questions that were often of a closed type requiring the recall of a procedure or term. These types of questions do not improve student achievement and can negatively affect student mindsets towards mathematics. There needs to be a shift in the design of practice questions to increase student achievement and encourage a growth mindset. In order to design more purposeful practice questions, teachers need to combine conceptual and procedural knowledge of the mathematics with the knowledge of the level of understanding their students possess (Epstein, & Van Voorhis, 2001). The amount and type of practice should vary according to the topic being studied and student need.

A comprehensive mathematics pedagogy should include student experiences of learning through problem solving, acquiring procedural fluency through conceptual understanding, developing a growth mindset, and consolidating learning through purposeful practice.

What Type of Professional Learning is Required?

Insufficient professional learning experiences for the elementary mathematics teachers in Ontario have resulted in what can be described as a collectively confused pedagogy. Some teachers still use more traditional practices emphasizing direct instruction and memorization while others have changed to use a more comprehensive pedagogy. Most teachers are somewhere between the two approaches using parts of traditional and comprehensive pedagogies or trying to teach comprehensive mathematics without sufficient understanding due to a lack of professional learning opportunities. As a result, many elementary mathematics students may experience confusion and frustration as teaching methods and messages change from year to year, resulting in decreased achievement. The goal of professional learning for elementary mathematics educators in Ontario should be a collective permanent change in teaching practice to reflect a comprehensive mathematics pedagogy. In order to reach this goal, key elements of professional learning need to be considered.

Effective professional learning needs to begin with a desire on behalf of the participants to learn. In teaching, this desire for professional learning occurs when reasons for participation are connected to student needs (Hord, 2009; Timperley et al., 2008). In the Ontario mathematics context, comprehensive mathematics should not be presented as top down, mandatory orders to follow but instead shared with educators in response to instructional challenges and problems they are facing. If comprehensive mathematics is to become a collective vision, teachers and administrators will need time and opportunities for discussion to share their thoughts, challenges, and frustrations as past instructional beliefs and practices are questioned. It will be important for

comprehensive mathematics to be shared as a collective goal at the school, board, and provincial levels. It needs to become a nonnegotiable part of the culture of teaching elementary mathematics in every school in Ontario and a touchstone for educators to refer to determine professional learning needs or next steps.

A permanent change in knowledge and practice at the classroom, school, board, and provincial levels will take time. For most elementary mathematics educators, moving to a comprehensive mathematics approach will not only require learning about new pedagogical techniques but also relearning the mathematical content they teach. They will need time to move beyond the traditional rules and procedures to understand underlying concepts through new models and procedures and shift to a different way of viewing mathematics as a subject to be understood rather than memorized in isolation. Teachers must be provided sufficient time not only to relearn the mathematics and change their beliefs but to try the new pedagogy in the classroom, share experiences, ask questions, reflect, and try again.

To improve the outcomes of professional learning, the inclusion of a knowledgeable other will be necessary to challenge past beliefs and practices, introduce new knowledge, and to focus and support educator learning to improve student learning (Cordingley, 2015; Cordingley et al., 2007; Timperly et al., 2008). This knowledgeable other needs expertise not only in the areas of math content and pedagogical knowledge but also in successful elements of professional learning. As a leader, the knowledgeable other must be willing to dig in and do the work beside the teachers and administrators. This could include planning, teaching and observing a lesson based on new knowledge. Learning is messy and theory does not always work in the actual classroom with students.

In order for professional learning to be successful, it will be vital to combine theory with practice in the classroom and to have a knowledgeable other that is willing to walk the talk.

In order to begin a collective, permanent change in instructional practice in the elementary mathematics classrooms of Ontario, high quality professional learning experiences must be provided. All educational leaders need to participate in this learning to signal its importance and to demonstrate a willingness to work and learn shoulder to shoulder with teachers.

How Can We Support Instructional Change In The Classroom?

In most traditional professional learning settings, new knowledge or theory is imparted to teachers who are then left on their own to apply this new knowledge by changing their instruction in the classroom. How will we know if there was a change in pedagogy to comprehensive mathematics? How will teachers receive support for the instructional roadblocks that arise when putting the theory into practice? In essence, we are asking how will we know what teachers have learned so we can support their next steps in learning. The answer to these questions is found in an instructional practice that is highly recommended for student learning yet seldom used in teacher professional learning, by using effective feedback through formative assessment (Black & Wiliam, 2009; Hattie & Timperley, 2007).

Formative assessment is a process used to gather information about student learning in order to identify learning needs and to provide feedback in order to help the student reach the learning goal (Heritage, 2007). In the context of professional learning formative assessment needs to happen through a reciprocal relationship between the

observer and the teacher. The observer receives feedback from the teacher about what they have learned by observing the teaching and listening to instructional questions and challenges the teacher may share after the lesson. The teacher then receives feedback from the observer through the sharing of observations through the lens of the professional learning goal and possible next steps to achieve that goal.

It will be important for Ontario elementary mathematics teachers to become comfortable with self and peer assessment in order to support one another in providing formative assessment and effective feedback. A knowledgeable other will not always be available; therefore, it will be important for teachers to be able to assess their own practice through video or audio recording or to rely on feedback from peers or principals. In order to provide consistent, effective feedback through formative assessment, knowledgeable others, principals, and teachers will need sufficient knowledge of math content, pedagogy, previous teacher learning, and assessment. It will take significant time for all of these educational stakeholders to acquire this knowledge. In the interim, in order to provide effective and consistent feedback for teachers, it will be important to develop assessment tools to support the formative assessment of elementary mathematics teachers, especially for Ontario principals and vice principals who perform the bulk of teacher assessments.

Currently in Ontario, a school principal is required to evaluate each experienced elementary teacher every 5 years using a standardized summative report (OME, 2017a). During this evaluation, there is some discussion between the administrator and teacher about general pedagogy but the discussions are limited in content by the subject being observed. In my experiences, these evaluations rarely impact teaching practices because

the primary purpose is summative, to provide a satisfactory or unsatisfactory rating. Different assessment tools will be required for the purpose of formative assessment with the goal of changing instructional practice in elementary mathematics. The purpose of formative assessment must also be clear to observers and teachers, it is about the collective learning of both, not an evaluative judgement.

In order to increase the effectiveness and reliability of formative assessment, multiple observations by multiple observers consisting of peers and administrators using a common assessment tool are recommended observing (Ho & Kane, 2013). These observers should receive training on using the assessment tool that includes evaluating common lessons. There are a number of assessment tools and frameworks specific to elementary mathematics that could provide a starting point for school boards interested in designing their own assessment tools specific to their professional learning goals.

To permanently change instructional practice in Ontario elementary mathematics classrooms, we need to provide support where it is needed most, in the classroom where the teaching and learning takes place. Formative assessment and feedback will play an essential role in initiating, sustaining, deepening, and extending professional learning to support the goal of changing pedagogy to increase student learning.

Discussion

The comparison and analysis of opposing viewpoints in the literature concerned with effective mathematics pedagogy uncovered more common ground than expected. As in most arguments, the disagreement often lies in not fully understanding each other's point of view. Critics of a problem-based pedagogy describe the approach as discovery learning (Alfieri et al., 2011; Kirschner et al., 2006; Stokke, 2015), often referring to

early constructivist approaches, and do not accurately depict the current recommended practice of teaching through problem solving (OME, 2003, 2006). In fact, the pedagogy of teaching through problem solving includes some of the recommendations provided by the critics of discovery learning such as the use of worked examples. If there were a discussion between the two sides, I believe they would agree that unassisted discovery learning is not an effective approach to mathematics education. A problem-solving approach guided by the teacher to scaffold learning with important mathematical ideas and according to student needs would be most effective. This approach must include the opportunity for students to share their thinking, ideas, and questions through the analysis of worked examples to clarify learning and misconceptions. Teaching through problem solving would be an important part of a comprehensive mathematics program but only represents one piece of the complex and specialized knowledge required for teaching.

The knowledge required for an elementary teacher to successfully implement a comprehensive mathematics pedagogy to teach the mathematics curriculum content goes well beyond what was needed to teach more traditionally in both scope and depth (Ball et al., 2005). In traditional, direct instruction the mathematical knowledge was often procedural, limited to the definitions, steps, or representations the teacher wanted to put into the student through memorization and practice. In order to use a more comprehensive pedagogy, teachers not only need to learn new knowledge about how to teach mathematics but they will also need to learn new content knowledge about the mathematical concepts they teach. Teachers will need this new knowledge to not only teach students how to do mathematics but to be able to answer the popular student question: Why? The knowledge needed for teaching goes so much further than being able

to do the math yourself. It is a complex and specialized knowledge that includes knowing broad mathematical content, where a student is within that content, what content the student needs next, and which pedagogical technique should be used. How will teachers be persuaded to not only change their teaching practices but to engage in learning new pedagogical and content knowledge that may take years to acquire? By changing their beliefs about learning and teaching mathematics.

If we truly teach who we are (Palmer, 1997), we need to take the time during professional learning to examine and discuss our beliefs about learning and teaching mathematics because our beliefs will not only impact the way we teach but, most importantly, what our students will believe about learning mathematics. Past discussions with elementary mathematics teachers revealed that their feelings and beliefs about learning mathematics were largely based on their experiences as elementary and secondary school students. Unfortunately, many elementary mathematics teachers had a fixed mindset when it came to their ability in mathematics and negative feelings towards the subject. By sharing and talking about their beliefs, these teachers felt some comfort in knowing there were others with similar beliefs and began to understand that these beliefs were a result of how they were taught mathematics. This raised the possibility of believing there was a better way to teach mathematics. It was by learning elementary mathematics in a way that promoted conceptual understanding that these teachers began to change their beliefs about their own abilities to understand mathematics that in turn sparked a need to change their teaching practice. It is impossible to truly achieve permanent change in practice without a change in beliefs. We need to include time during professional learning for teachers, educational assistants, school administrators, and

superintendents to share and examine their beliefs and understand how everyone's beliefs impact the learning of mathematics in the classroom.

Through my review of the literature and experiences in the field, it has become evident that theory, practice, and feedback must all be included to increase the effectiveness of professional learning. Too often in the past, teachers attended a professional learning session to receive the theory or new knowledge and then were sent back to the classroom to implement it on their own. Professional learning must include opportunities for teachers to practise or try to implement theory in the classroom, share experiences, ask questions, and try again. Different types of lesson study can provide effective professional learning experiences where groups of teachers can co-plan, co-teach, and observe a mathematics lesson based on new theory. After the lesson the group can share their observations, questions, and student work to analyze the lesson and how it could be improved. This type of professional learning includes theory, practice and feedback while sharing the responsibility of the lesson and the results amongst the whole group instead of one teacher. Doctors have rounds, lawyers have mock trials, and pilots have flight simulators to try theory in practice, to be observed, and to receive feedback for professional learning. It is time for these components to become the foundation for effective professional learning for teachers.

Implications

On the basis of the evidence presented in this portfolio through a review of the literature, selection of the artifacts, and sharing of professional experiences, it is clear that elementary mathematics instruction in Ontario should be based on a comprehensive mathematics pedagogy in order to improve student achievement. This pedagogy should

include the elements of (a) teaching through problem solving, (b) developing procedural fluency through conceptual understanding, (c) purposeful practice, and (d) developing a growth mindset. Decreasing standardized test results and collectively confused pedagogical practices are signalling the need for change in elementary mathematics instruction in Ontario. Implementing and sustaining a permanent change in practice to comprehensive mathematics will require significant professional learning for all elementary educators including teachers, principals, and superintendents.

Comprehensive mathematics needs to begin as a shared vision for schools, boards, and the province and eventually become a nonnegotiable for teaching elementary mathematics, embedded in all schools as the way to teach math. Developing the shared vision of comprehensive mathematics will require the interest and engagement of educational stakeholders in professional learning. The best way to spark that interest is to connect current instructional issues with solutions found in comprehensive mathematics. For teachers, the instructional problems will relate to the students in the classroom; for principals, instructional problems may relate to supporting mathematics teachers in their school' and for superintendents, the instructional problems may relate to supporting their principals or the board. It is vital that all educational stakeholders in the school and board engage in professional learning about comprehensive mathematics to (a) promote consistent practice in the classroom, (b) provide appropriate professional learning support, (c) select appropriate teaching resources, and (d) enable principals and superintendents to provide effective feedback. The development of a board-wide vision of comprehensive mathematics in all schools and the larger community will take time but it is an important first step in creating change.

In order to implement the vision of comprehensive mathematics in the classroom, teachers will require professional learning that brings the theory into practice. We need to reduce the number of large professional learning sessions where theory is shared with teachers when they are often sent out on their own to figure it out in the classroom. Instead, professional learning needs to happen in schools where new knowledge can be tried in classrooms with the students they teach. Lesson study, co-teaching and observing, coaching, and collaborative inquiry are examples of professional learning models that include opportunities for putting theory into practice. School principals and vice principals should also participate in this type of learning and perhaps even teach some time to gain the knowledge needed for providing effective observation and feedback for mathematics teachers. Moving professional learning to smaller settings will require more time and more knowledgeable others to lead the learning.

Effective professional learning experiences will require a team of facilitators who possess the complex and specialized knowledge required to effectively teach elementary mathematics. A comprehensive mathematics pedagogy requires a deep and broad understanding of the pedagogy, the mathematical content, how students interact with that content, and next steps in learning for both teachers and students. Without a knowledgeable other to facilitate the learning, well-intentioned leaders and participants may unknowingly encourage the use of instructional practices, resources, and software that are not aligned with comprehensive mathematics causing confusion and frustration. Most Ontario school boards will use consultants, learning support teachers, or coaches as facilitators and will face the challenge of not having enough knowledgeable others to meet the professional learning needs of the system. Boards will need to be creative in

coming up with ideas that will make the best use of the knowledgeable others they have while maintaining the quality of the professional learning.

During and after professional learning experiences, teachers will need feedback and support in order to implement and sustain the instructional changes needed in the move towards a permanent comprehensive mathematics pedagogy. Formative assessment for improving teaching needs to become common practice in Ontario. Effective formative assessment and feedback can be modelled during professional learning experiences such as lesson study when the observers of the lesson share their reflections and the collective group provides possible next steps for instruction. Formative assessment could take place in a variety of ways including self assessment through the review of a video taped lesson, peer assessment by a colleague who observes a math lesson, and administrator observation, not for the purpose of evaluation but to provide ideas that will support student learning. It will be important for peers and administrators who are observing to possess adequate knowledge of comprehensive mathematics in order to provide accurate assessment and feedback. Boards may consider developing common observation tools and training to ensure consistent assessment and feedback is being provided.

The evidence and suggestions provided in this portfolio for improving elementary mathematics education in Ontario are not exhaustive. There is more work that needs to be done and more questions that need to be answered. How much of an effect does formative assessment and feedback have on professional learning? How do we support teachers in helping students with gaps in learning? To really bring theory and practice together, it will be important for educational researchers and elementary educators in

Ontario to come together to share questions, conduct research, and find answers to share with the system in the continuing quest to improve student learning in mathematics.

Conclusion

I have appreciated the opportunity to create and share this portfolio of learning as part of my completion of the Master of Education program at Brock University. This has been a reflective process that has resulted not only in a representation of what I have learned through this program, but also what I have learned through my experiences in mathematics education. The recommendations developed in this portfolio including a comprehensive mathematics pedagogy, effective professional learning, and effective teacher assessment and feedback are supported by a review of the literature; however, my beliefs about mathematics education and professional learning that were developed through my experiences as a mathematics student, teacher, and consultant provided the foundation and direction for these recommendations.

I come away from this experience realizing that a permanent change in pedagogy requires a permanent change in beliefs. Too often in professional learning, there is a lack of discussion or sharing of beliefs about teaching, especially if those beliefs do not align with the pedagogy being promoted. If teachers do not believe in the pedagogy, why would they use it? In order to change beliefs, it will be important to share our current beliefs, uncover their origin, and understand their impact on our instruction. My negative experiences as an elementary mathematics student played a role in my quest to find a different pedagogy as an elementary mathematics teacher. However, what about my colleague who, in spite of experiencing the same traditional pedagogy as a student, learned and enjoyed mathematics and believes there is no reason to change? It is through

the collective sharing of beliefs that my colleague may be surprised to discover that traditional mathematics instruction was not effective for the majority of students. In order to move towards a shared pedagogical vision, we must engage in discussions about our beliefs.

In completing this portfolio and thinking about my journey of learning about mathematics education and professional learning, I was struck by the symbiotic relationship of theory and practice. Early frustrations and questions about the practice of teaching mathematics traditionally lead me to theory shared in professional learning experiences suggesting a different pedagogy. In attempting to try this new theory in my classroom, I often ended up with unsuccessful lessons and many questions so I would return to try to find answers in the literature. I continued to bounce back and forth between theory and practice to deepen my learning. It was through these experiences that I found barriers to my professional learning between theory and practice.

Research and statistical terminology provided in the literature were difficult to understand without experience. The theory was often presented in broad strokes and academic language without specific instructions needed for application in the classroom. Teaching through problem solving sounds great in theory but how do you actually teach a lesson on fractions that way? I believe the most effective professional learning will occur in experiences that operationalize theory by applying it in the classroom. I also believe that researchers would benefit by joining teachers in the classroom to support the use of theory in practice to create new research questions based on the needs of the teachers and their students.

In completing this portfolio and my Master of Education experience, I have no doubt as to the impact it has had on my learning and in my role as an educator. It is my hope that the ideas and suggestions provided in this portfolio will be helpful to others interested in fixing the Ontario elementary mathematics engine.

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Experience

Learning Services Consultant, JK to Grade 6, WRDSB, 2007 – present

- created and implemented system-wide training for elementary mathematics teachers based on the CIL-M framework
- adapted the CIL-M framework to meet other professional learning needs including guided reading and early learning
- implemented the use of a math intervention support for the system and validated student results with an independent evaluation tool
- designed and implemented research projects concerned with measuring the effectiveness of a variety of elementary math resource supports
- supported administrators and schools in analyzing data, creating school success plans and determining professional learning next steps for staff

Program Consultant, Mathematics Grades 4 to 6, WRDSB, 2006 - 2007

- created and implemented system-wide training for mathematics teachers in the junior division, connecting session content with related demonstration visits and classroom applications
- examined professional development effectiveness by developing qualitative and quantitative data surveys to measure changes in pedagogy and content knowledge
- facilitated and monitored a mathematics demonstration class
- initiated and supported an OFIP mathematics coaching project in two elementary schools
- produced and presented training materials and organized classroom visits for teachers as part of the NTIP junior team

Education Officer, Ontario Ministry of Education, 2004 - 2006

- provided recommendations for the creation, organization and implementation of provincial numeracy initiatives as a member of the Kindergarten to Grade 6, Education Foundations Numeracy Team
- developed, edited and presented mathematics training modules to mathematics leaders from across the province
- authored and edited mathematics guides for distribution to all elementary teachers in Ontario
- created and edited content materials, including video scripts for web modules on the eWorkshop web site

Program Consultant, Mathematics Kindergarten to Grade 8, 2002 - 2004

- created and implemented system training sessions for kindergarten to grade 9 in the areas of mathematics, differentiated instruction, and assessment
- organized and facilitated the WRDSB Early Math training team and training sessions for primary lead teachers
- helped initiate and plan the primary mathematics demonstration classrooms

Leadership Experience

Problem Solvers Department Editor, National Council of Teachers of Mathematics Teaching Children Mathematics Journal, 2013-14

Member, WRDSB Math Committee, 2013-14

- attended meetings and provided input regarding guidelines for math instruction for the system grades 1 - 12

Presenter, WRDSB Parent Involvement Committee Rise to Success Conference, 2014

- presented an elementary mathematics information session to WRDSB parents attending the conference

Member, Pearson Education Math Leadership Group, 2012-13

- attended meetings and provided input regarding effective planning resources and supports for elementary math instruction

Content Specialist, ETS Canada, EQAO Grade 3 Team, 2008-2009

- facilitated writing teams, edited and designed banks of questions for submission to EQAO

Instructor, Primary/Junior Mathematics AQ Course, WLU 2006 - 2007

- created, organized and instructed course content materials
- created course outlines for Parts 1, 2 and Specialist courses

Presenter, Hamilton-Wentworth DSB Professional Development Day, 2005

- presented mathematics sessions for elementary teachers

Course Designer, OISE/University of Toronto Midwestern Centre, 2005

- created a grade 7 to 12 course entitled "Show Me How to Teach Math"

Member, Program Committee, OAME 2004 Conference, 2003 - 2004

- helped organize the Ontario Association for Mathematics Education 2004 Conference

Writer, Curriculum Revision Team, Ontario Ministry of Education, 2004

- drafted and revised the elementary mathematics curriculum

Member, Junior Mathematics Expert Panel, Ontario Ministry of Education, 2004

- provided input and authored content material for *Teaching and Learning Mathematics – The Report of the Expert Panel on Mathematics in Grades 4 to 6 in Ontario*
- presented the *Report of the Expert Panel* to provincial school board leaders
- highlighted the main points of the report and facilitated discussion with an audience of superintendents and principals

Education

Brock University, Masters of Education, expected completion 2017

University of Toronto, Bachelor of Education, Primary/Junior, 1990 - 1991

University of Waterloo, Bachelor of Arts, Honours English, 1985 - 1989

Additional Qualifications

Intermediate and Senior English

Computers in the Classroom Part 1

Computers in the Classroom Part 2

Appendix B

Essay: What's the Problem? An Exploration of Teaching Mathematics Through Problem Solving

What's The Problem?
An Exploration of Teaching Mathematics Through Problem Solving

Ed Enns, B.A., B.Ed.

Department of Graduate and Undergraduate
Studies in Education

Submitted in partial fulfillment
of the requirements for EDUC 5P55

Faculty of Education, Brock University
St. Catharines, Ontario

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Introduction

“Problem solving is central to learning mathematics. By learning to solve problems and by learning through problem solving, students are given numerous opportunities to connect mathematical ideas and to develop conceptual understanding. Problem solving forms the basis of effective mathematics programs and should be the mainstay of mathematical instruction.” (Ontario Ministry of Education, 2005, p. 11) This direction comes from the current Ontario elementary mathematics curriculum that was revised in 2005. In the eight years since its release, I have worked with hundreds of elementary mathematics teachers in an attempt to support the implementation of the suggested pedagogy of teaching through problem solving. My observations of teaching practice and conversations with teachers have indicated a limited adoption of this pedagogy in elementary mathematics classrooms. Instead, some educators chose to teach from the textbook, others chose a more traditional style of teacher directed instruction. Some early adopters tried this new math pedagogy but returned to traditional teaching methods. Why has the implementation of teaching through problem solving been so limited? Over the past decade educators, administrators, parents, academics and the media have voiced important questions regarding teaching through problem solving that may reveal underlying causes for the minimal adoption of this pedagogy. What does learning or teaching through problem solving really mean? What evidence is there that this approach is better than traditional methods? What knowledge, strategies and mindsets are needed to teach this way? In this paper I will focus in on the first question and discuss implications for future research and partnerships in the math education community.

What Does Teaching Through Problem Solving Really Mean?

Answering this question is important as it provides the foundation for investigating all other questions pertaining to teaching through problem solving regarding instruction, assessment, student achievement and efficacy. Historically there have been a variety of labels for this type of instruction such as teaching through problem solving, problem-based learning, and learning through problem solving. For the purposes of this paper I will refer to this pedagogy as teaching through problem solving (TTPS). In this section a variety of definitions of TTPS will be explored and discussed.

Discovery-Based Definitions

Kirschner, Sweller and Clark (2006) include problem-based learning in a list with discovery learning, inquiry learning and experiential learning, describing them as equivalent approaches under the umbrella of a minimally guided approach to teaching and learning (p. 75). The authors go on to describe this type of instruction as having minimal or no guidance from the teacher. Similar interpretations of teaching through problem solving have been implied in the media including “*Why is it your job to teach your kid math?*” (Macleans, 2012) and “*Program could help kids get jump-start in math*” (Globe and Mail, 2010) in which a researcher argues that “research does not support the idea that the ‘discovery’ approach to teaching math is the most effective”. These definitions and interpretations suggest that students are given problems to learn new mathematical content through ‘discovery’ with little or no guidance from the teacher and that knowledge is not presented or explained so students must construct it on their own.

Discovery-based definitions are often used in educational psychology articles such as those referenced in Kirschner, Sweller and Clark (2006). They usually reflect

early ideas of constructivism and problem-based learning and represent one point of view or interpretation. In my experiences, many teachers begin with a discovery-based understanding of TTPS but their interpretation changes over time as they reflect on their practice, and explore professional resources that are based on mathematics education research. This research has evolved over time from early constructivist and problem-based theories into more specific descriptions of teaching through problem solving in the discipline of mathematics.

The Evolution of TTPS Definitions

In the year 2000, NCTM (National Council of Teachers of Mathematics) published *Principles and Standards for School Mathematics*, a curriculum framework for mathematics education. This document was important as it not only included mathematical content standards but also highlighted process standards of problem solving, reasoning, connections and communication. This publication contributed to the inclusion of the mathematical processes in the revision of regional mathematics curricula throughout North America, including the 2005 Ontario mathematics curriculum and the 2011 Common Core State Standards in Mathematics in the United States. A new emphasis on teaching mathematics through problem solving with an awareness of the mathematical processes or the actions of doing mathematics became prominent in a wide range of curricula.

In many math curriculum documents, the process of students learning through problem solving is highlighted but there is a lack of detail concerning the meaning of this term in a practical sense for teachers. My opening quote from the Ontario curriculum document is accompanied with justifications of why TTPS is important, but what is

missing is a meaningful discussion of what it looks like in the classroom. Regions, schools and individual teachers have been left to their own interpretations of the meaning of TTPS and many adopted a discovery-based interpretation. As a result, there were numerous questions and issues associated with how TTPS should be implemented in mathematics classrooms. This created an impetus for the clarification of the meaning and implementation of TTPS as well as the need for further research.

In Ontario, the Ministry of Education published support documents, *K-6 Guides to Effective Instruction in Mathematics* (2003 – 2008), to provide teachers with practical ideas for putting theory into practice. These guides were based on research included in earlier provincial expert panel reports on mathematics (2003 & 2004). *The Report of the Expert Panel on Early Math* (2003) provides an explanation of TTPS that differs from earlier discovery-based definitions. “Problem solving is more than the application of skills. Problem solving in a classroom generally begins with the teacher presenting the problem, students exploring and working on a solution to the problem, and then teacher and students consolidating and reflecting” (p. 16).

The omission of the consolidation and reflection stage of problem solving in discovery-based definitions of TTPS is significant. The consolidation and reflection stage of problem solving provides time for the students to develop conceptual understanding and content knowledge through solutions that are shared by their classmates. Students have the opportunity to pose ideas, ask questions and clarify their thinking around important mathematical ideas and processes. Interestingly, Kirschner et al. (2006) suggest that in lieu of problem-based learning the use of worked examples through guided instruction is proven to be more effective (p.80). In essence, the consolidation and

reflection portion of learning through problem solving provides students with worked examples for discussion and reflection.

This ‘evolution’ of the meaning of TTPS came about as a result of a review of research at the time including formal academic research and informal research from classroom implementation. Much of the literature reviewed in the Ontario documents was based on the work of pioneers in math problem solving research. Cathy Fosnot at Math in the City in New York who spent time at the Freudenthal Institute and worked with the Realistic Mathematics Education group. Doug Clements, Juanita Copley, and Julie Sarama who researched how young children learn mathematics. Hiebert, Fuson, Carpenter, Fennema, Schoenfeld, Lester and Charles who all researched and wrote articles on the topic of TTPS during a time when there were real tensions between advocates for a more traditional rote learning of mathematics and those suggesting the ‘new math’ emphasizing conceptual understanding and problem solving.

The practical definition of teaching through problem solving continues to evolve as new researchers build on the work of the pioneers. These new researchers include educators doing informal research through professional development models such as lesson study. As educators share observations and reflections about TTPS, they have provided important practical recommendations that have improved problem solving experiences for teachers and students and expanded their understanding of what problem solving means. What have we learned about TTPS? What do we think it means now?

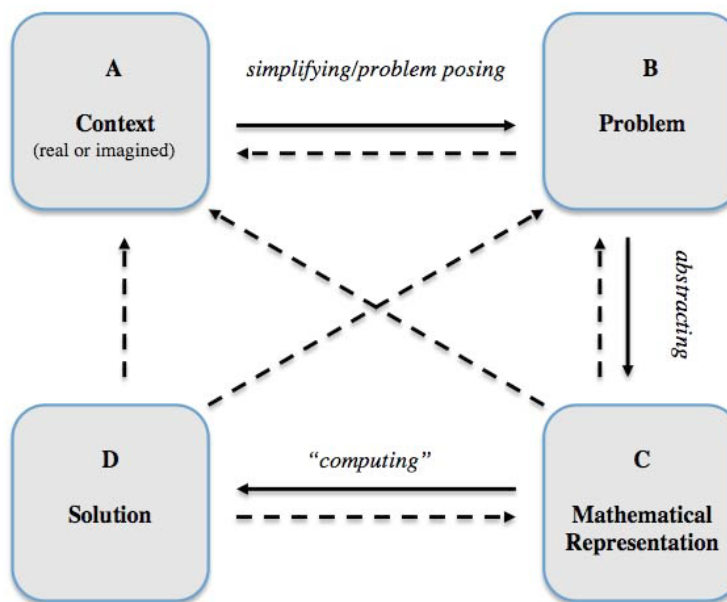
Current Understandings of Teaching Through Problem Solving

The successful implementation of TTPS relies in part on an understanding of what the activity of problem solving means. What is problem solving? Historically, problem

solving has often been defined as a task for which an individual does not have an obvious or immediate answer. This definition is a vague and simple explanation of problem solving that does not address the complexity of behaviours, interactions and processes involved in solving a problem as suggested by Lester & Kehle in 2003. “Successful problem solving involves coordinating previous experiences, knowledge, familiar representations and patterns of inference, and intuition in an effort to generate new representations and related patterns of inference that resolve some tension or ambiguity (i.e., lack of meaningful representations and supporting inferential moves) that prompted the original problem-solving activity” (p. 510). Lester (2013) argues that this definition suggests students must have numerous experiences in solving problems, develop content knowledge, a comfort in using a variety of representations and learn how to recognize and construct patterns of inference (p 249). In light of this more detailed definition of problem solving, what implications does this suggest for instruction?

In my experience, both traditional problem solving instruction and teachers that are new to TTPS often interpret the pedagogy to entail teaching the concepts and procedures first through transmission and then having students translate real-life contexts into mathematical questions to be solved using the skills and knowledge that had been recently memorized. This approach is often used in traditional textbooks and is recommended in some literature including Kirschner et al. (2006) referencing Kyle (1980) “inquiry is a systematic and investigative performance ability incorporating unrestrained thinking capabilities after a person has acquired broad, critical knowledge of the particular subject matter through formal teaching processes (p.79).

Lester (2013) argues that problem solving should not be separated from content knowledge or assume that math understanding is needed to problem solve but rather the inverse that problem solving leads to math understanding and mathematical activity or processes. (p. 251). He contends the new perspective on problem solving involves the real world and the math world but math processes are being learned or understood and the steps in the math are related to actions on elements in the real world, that meaning making is central. (p. 255). This interplay between the real world and the math world is highlighted by others including Dan Meyer (2010) who emphasizes the importance of having students generate problems from real life contexts such as photographs or video instead of being given the problem via the traditional text based problem. Lester and Kehle (2003) propose a new model to represent the complex activity involved in problem solving represented in Figure 1 below (p.258) to represent how “typically the problem solver moves back and forth between the two worlds- the everyday problem world and the mathematical world- as the need arises” (p. 256). I believe this new model is a much more accurate representation of the mathematical activity involved in problem solving and a significant improvement of more traditional representations of problem solving such as Polya’s four step problem solving model shared in the Ontario curriculum (2005): understand the problem; make a plan; carry out the plan; and look back to check the results (p. 13, as cited in Polya, 1945). Many educators have used Polya’s model as a graphic organizer for student solutions to all math problems. The use of this organizer oversimplifies the mathematics activity involved in solving a problem and implies that problem solving always follows the same four steps in a linear fashion.



Note. Dashed arrows denote "comparing"

Figure 1. A model of complex mathematical activity

Lester and Kehle's model provides educators with a new way of considering the activity of problem solving that may improve problem posing, assessment and student creativity through choice of representation.

The Problem Solving Environment

Understanding the complex activity of problem solving is a vital component in TTPS. What about the learning environment? Do students learn through problem solving individually or is it more of a social construction of learning? Traditionally, mathematics learning has been experienced in quiet isolation and conversation between students has often been discouraged. Jo Boaler (2000) relates that psychological learning theories have been prevalent in math education but currently other perspectives have been considered, including anthropological and sociological, to understand teaching and learning mathematics (p. 379). Boaler (2000) expands on Lave and Wenger's work (1991) that suggests knowledge ability is a function of the environment. "Within mathematics

education, the classroom community, including the implicit and explicit norms and practices that prevail, becomes extremely important, not as a vehicle for learning but as an intrinsic part of the knowledge that is generated and used” (p. 379-80). Recent research (Boaler, 1997; Brown, Collins & Duguid, 1989, Cobb, 1994; The cognition and Technology Group at Vanderbilt, 1990; Watson, 1998) has moved “beyond the individual as primary unit of analysis to the communities in which students operate, the relations they form there, and the personal and cultural histories that they bring to their knowing” (p. 380). This focus on the learning community is discussed by Cathy Fosnot (n.d.), “Our work is driven by the desire to transform classrooms into communities of mathematicians: places where children explore interesting problems and, like mathematicians, engage in crafting solutions, justifications, and proofs of their own making”. (p. 1). Building on previous research suggesting the importance of the learning community, Boaler (2000) conducted a study to answer two questions: how do students view the world of the school mathematics classroom? and what impact do such views have upon knowledge production and use?” (p. 381).

Boaler (2000) conducted her research with 1 000 students from 6 different schools. All of the students experienced traditional direct teaching methods in their mathematics classes for the majority of the time. She collected data from lesson observations, questionnaires and in-depth student interviews. Boaler found three major themes from her data: monotony, lack of meaning and individual learning. Students were bored with math class and didn’t see how it connected to their lives presently or in the future. On a survey 57% of the students felt math was more about memorizing than thinking. “The students located their learning of mathematics within a broad, social

domain, which is entirely consistent with situated perspectives on learning, while the schools regarded the students as individual learners who could be shifted from group to group (p. 390). Boaler (2000) argues that humans are inherently social so why would math be taught individually? She concludes that “school mathematics, for many of them, was of another world and to fully engage in that world, students needed to suspend their knowledge of the real world, suppress their desire to interact with others, and strive to reproduce standard procedures that held little meaning for them.” (P. 392). Boaler’s study reinforces the negative effects traditional instruction by telling can have on student engagement and efficacy in learning mathematics. The very nature of the problem solving activity suggested in Lester and Kehle’s model lends itself to the work of a ‘community of mathematicians’ who generate, share, test and validate ideas to answer problems generated from their lives.

Conclusions

The majority of teachers I work with are familiar with the term teaching through problem solving and are willing to try it in their mathematics classrooms. What they require is a more detailed explanation of what this pedagogy means in a practical sense. Recent research from the academy can provide more clarity concerning the meaning of the teaching and learning of problem solving and needs to be shared with educators to inform their practice. Informal research concerning effective practices during teaching through problem solving experienced by educators should be shared with the academy to inform their research.

Members of the academy who generate theories and ideas and educators who bring theory to practice need to come together to form their own learning community.

Joint projects between researchers and educators that go beyond the quantitative data of student achievement to consider qualitative data and the voices of teachers and students would be powerful in the continued evolution of the meaning of teaching through problem solving. Starting points for this research might include: What empirical evidence is there that TTPS is a better pedagogy for teaching and learning mathematics than traditional methods? What knowledge, strategies and mindsets are needed for teachers to use this pedagogy effectively?

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Appendix C

PowerPoint Presentation: Parent Math Night

Parent Math Night



(Pfohl, 2010)

Topics

1. Introductions.
2. Beliefs about learning mathematics.
3. Let's try some math ourselves.
4. What do we want for our children as students of mathematics?
5. How and why is mathematics education changing?
6. Looking at PISA and EQAO results.
7. How can I support my child in learning mathematics?
8. Questions.

If Math were an animal what would it be?

Introduce yourself to someone around you and share what animal you chose and why?

Where do these animals come from?

Can we build student beliefs while addressing basic facts and computations?

What about basic facts?

1. They have always been in the curriculum.
2. Encouraging instruction to begin with conceptual understanding and thinking.
3. Students still need practice to consolidate the facts.
4. When students understand the mathematical patterns and relationships underlying the basic facts they can extend this understanding to multi-digit mental computations.

Let's Try Some Math

$$\begin{array}{r} 400 \\ 200 \\ 150 \\ 80 \\ 16 \\ \hline +15 \end{array}$$

Math Makes Cents?

Graphic containing the following Canadian Currency:

2 Two Dollar Coins

2 One Dollar Coins

6 Quarters

8 Dimes

3 Nickels

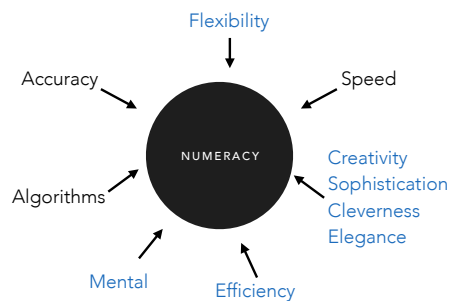
16 Pennies

$$\begin{array}{r} 400 \\ 200 \\ 150 \\ 80 \\ 16 \\ \hline +15 \end{array}$$

$$\begin{array}{r} 476 \\ +245 \\ \hline 600 \\ 110 \\ \hline 11 \\ 721 \end{array}$$

Memorization vs. Automaticity

1. Memorization - committing answers to memory without thinking (no relationships between facts)
2. Automaticity - relies on thinking but answers still need to be produced in a few seconds. These answers will eventually be remembered
3. Not about whether facts should be memorized but how they will be memorized - through thinking
4. More students are able to remember their facts this way.



p. 4, Weber Harris, Building Powerful Numeracy for Middle and High School Student, 2012

What do we want for our children in terms of mathematics education?

Employer Demand For Bachelor Degrees

1. Finance
2. Accounting
3. Computer Science
4. Mechanical Engineering
5. Business Administration

National Association of Colleges and Employers

What is a mathematically literate person?

Mathematical literacy is an individual's capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgements and to use and engage with mathematics in ways that meet the needs of that individual's life. Success in mathematics goes beyond knowing mathematical facts and procedures; it also means being able to reason mathematically and to have the ability to interpret and solve mathematical problems.

EQAO

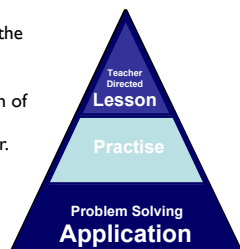
How Do We Promote Mathematical Literacy?

A Traditional Approach

Mathematics comes from the teacher.

Emphasis on memorization of procedures and formulas, speed and the right answer.

We solve word problems at the end.



Why Change?

1. As many as 6 out of 10 adults deal with math anxiety.
2. Students who rely on memorization to compensate for lack of understanding typically 'hit a wall' around grade 10 or 11.
3. Approximately 1 out of 3 students are not able to take Grade 9 academic math.
4. Ginsburg describes mathematics as a way of making sense of the world (2002). Yet for the majority of adults, mathematics is seen as a mystery or a subject for the gifted few.
5. In the past 30 years there has been no growth in the percentage of University students in math intensive degrees.

2013 PISA Results

- PISA (Programme for International Student Assessment) 2013
- 15 year olds randomly selected across Canada
- 96.4% of Canadian students got basic skills q's.
Only 4.3% got highest problem solving questions

Tweet from Cathy Bruce, Trent University

2013-14 EQAO Results

Bruce Rodrigues, CEO of EQAO speaking about 2013-14 results:

- Pr and Jr assessment best strand was NSN
- Pr and Jr assessments best category was Knowledge
- Pr, Jr and Gr. 9 worst category was Thinking
- students know basic facts
- students know how to compute
- difficulty knowing which operation to use
- difficulty bringing the computation back to context to make sense of the answer

How is Mathematics Education changing?

Comprehensive Math Instruction

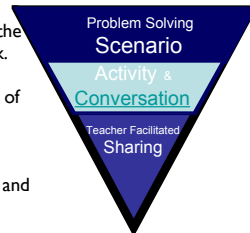
- Engaging students in mathematical learning and building a "growth mindset"
- Problem-based learning focused on conceptual understanding and application of skills in context
- Purposeful practice for consolidation
- Integration of mathematical skill development (e.g., fluency and automaticity, mental mathematics, estimation skills)

A Different Approach Teaching Through Problem Solving

Mathematics comes from the students through the work.

Emphasis on making sense of mathematics and moving towards efficiency.

Encouraging perseverance and growth mindset.

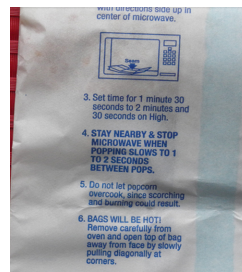


Average Retention Rates Related to Student Engagement

Lecture	5%
What we read	10%
What we hear	20%
What we see	30%
What we see and hear	50%
What is discussed with others	70%
What we practice by doing	75%
What we experience personally	80%
What we teach others and use immediately	90%

Ekwall in Harper and O'Brien, p. 15, Student Driven Learning, 2012

Popcorn Problem



(Enns, 2012)

24 students

BAGS	SECONDS
1	150
10	1500
20	3000
2	300
4	600
24	3600

$$24 \times 2 \frac{1}{2} \text{ minutes}$$

$$24 \times 2 = 48 \text{ minutes}$$

$$24 \times \frac{1}{2} = 12 \text{ minutes}$$

$$48 + 12 = 60 \text{ minutes}$$

$$1 \text{ bag in } 2.5 \text{ minutes}$$

$$2 \text{ bags every } 5 \text{ minutes}$$

$$12 \times 2 \text{ bags} = 24 \text{ bags}$$

$$12 \times 5 \text{ minutes} = 60 \text{ minutes or } 1 \text{ hour}$$

How Do We Change?

Change in Mathematics Education

- Educators continue to be involved in mathematics professional development to deepen understanding of how to support student learning
- Teaching through problem solving, emphasizing conceptual understanding as well as procedural understanding
- Belief that all students can be successful in learning mathematics
- Use of Number Strings/Mini Lessons for basic facts and mental computation
- We need our parents to support us in aligning these beliefs with our students

How can I support my child?

1. Talk with your child's teacher when you have questions
2. Be Positive - every child can learn mathematics with persistence and effort
3. Be Less Helpful - always try to have the math come from your child and not the other way around
4. Ask questions that encourage understanding ("Why did you do that?", "Why does that work?", "How do you know you are right?", "Is there another way you could do it?")
5. Connect Mathematics to Real Life - shopping, cooking, construction, time management.
6. Encourage your students to question and wonder with them.
7. Set High Expectations - students need to learn to persevere to adjust thinking and strategies if their first attempt is unsuccessful

Ontario Ministry of Education Resources

<http://www.edu.gov.on.ca/eng/curriculum/elementary/math.html>
Curriculum and resource documents for elementary mathematics.

<http://www.edu.gov.on.ca/eng/curriculum/secondary/math.html>
Curriculum and resource documents for secondary mathematics.

<http://www.edu.gov.on.ca/eng/literacynumeracy/parentGuideNumEn.pdf>
Kindergarten to grade 6 booklet with tips on how to help your child with math.

<http://www.edu.gov.on.ca/abc123>
Ministry of Education website available in 15 languages with tips for parents on how to support their child's learning in a variety of subject areas.

<https://homeworkhelp.illc.org/>
Homework Help is a free online math help resource for students in Grades 7-10. Homework Help provides free, live one-on-one tutoring from Ontario teachers.

TED Talks on Math Education

Dan Meyer - Math Class Needs a Makeover
http://www.ted.com/talks/dan_meyer_math_curriculum_makeover.html

Conrad Wolfram - Teaching Kids Real Math with Computers
http://www.ted.com/talks/conrad_wolfram_teaching_kids_real_math_with_computers.html

Carol Dweck - The Power of Believing You Can Improve
https://www.ted.com/talks/carol_dweck_the_power_of_believing_that_you_can_improve

Angela Duckworth - The Key to Success? Grit
http://www.ted.com/talks/angela_lee_duckworth_the_key_to_success_grit

Questions

Appendix D

Inventory Results: Education Philosophy Inventory, Teaching Perspectives

Inventory for Ed Enns

Education Philosophy Inventory

RESULTS

EPI Score Sheet: Below, the numbers you circled for each statement (1-36) recorded and totaled under appropriate perspective. The highest total indicates your educational philosophy.

Essentialism

Essentialism was a response to progressivism. It advocates a conservative philosophic perspective. The emphasis is on intellectual and moral standards that should be transmitted by schools. The core of the curriculum should be essential knowledge and skills. Schooling should be practical and not influence social policy. It is a 'back to basics' movement, which emphasizes facts. Students should be taught discipline, hard work, and respect for authority. Influential essentialists: William Bagley, H.G. Rickover, Arthur Bestor, William Bennett; E.D. Hirsch's Cultural Literacy could fit this category.

Total: 11 (Sum of Questions: 1, 7, 13, 19, 25, 31)

Behaviorism

Behaviorists deny free will and maintain that behavior is the result of external forces, which cause humans to behave in predictable ways. Behaviorism is linked with empiricism, which stresses scientific experiment and observation. Behaviorists are skeptical about metaphysical claims. Behaviorists look for laws governing human behavior the way natural scientists look for empirical laws governing natural events. The role of the teacher is to identify behavioral goals and establish a reward system to achieve goals. Influential behaviorists: B.F. Skinner, Ivan Pavlov, J.B. Watson, Benjamin Bloom.

Total: 8 (Sum of Questions: 2, 8, 14, 20, 26, 32)

Progressivism

Progressivism focuses more on the child than the subject matter. The students' interests and personal growth are important. Learners should be active and learn to solve problems by reflecting upon their experience. The school should help students develop democratic personal and social values. Because society is always changing, new ideas are important to make the future better than the past. Influential progressives: John Dewey, William Kilpatrick, Francis Parker.

Total: 23 (Sum of Questions: 3, 9, 15, 21, 27, 33)

Existentialism

Existentialism is a highly subjective philosophy that stresses the importance of the individual and emotional commitment to living authentically. It emphasizes individual choice over the importance of rational theories, history, and social institutions. Jean Paul Sartre, the French philosopher, claimed 'Existence precedes essence.' Sartre meant that people are born and must define themselves through personal choices. Influential existentialists: Jean Paul Sartre, Soren Kierkegaard, Martin Buber, Martin Heidegger, Gabriel Marcel, Friedrich Nietzsche, Albert Camus, Carl Rogers, A.S. Neill, and Maxine Greene.

Total: 22 (Sum of Questions: 4, 10, 16, 22, 28, 34)

Perennialism

Perennialists advocate that the aim of education is to ensure that students acquire knowledge about the great ideas of Western culture. Human beings are rational, and it is this capacity that needs to be developed. Cultivation of the intellect is the highest priority of an education worth having. The highest level of knowledge in each field should be the focus of curriculum. Influential perennialists are: Robert Maynard Hutchins, Mortimer Adler, Allan Bloom.

Total: 16 (Sum of Questions: 5, 11, 17, 23, 29, 35)

Reconstructionism

Reconstructionists advocate that schools should take the lead to reconstruct society. Schools have more than a responsibility to transmit knowledge they have the mission to transform society as well. Reconstructionists go beyond progressivists in advocating social activism. Influential reconstructionists: Theodore Brameld, George Counts, Paulo Friere, Henry Giroux.

Total: 19 (Sum of Questions: 6, 12, 18, 24, 30, 36)

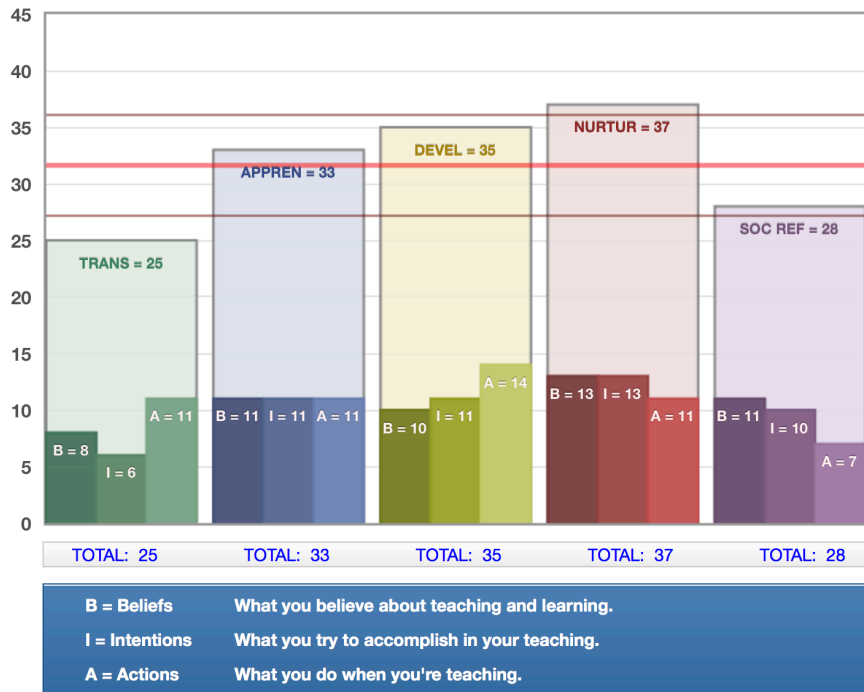
Conclusion:

Your responses to the Inventory probably favor several philosophic perspectives. Look at your highest and lowest scores. The high scores indicate those perspectives most consistent with your views about teaching, learning, curriculum and governance: the four commonplaces of educating.

For example, in question 1, if you believe the curriculum should emphasize a set fixed body of knowledge, you probably scored high in essentialism. If you believe curriculum should emphasize students' personal interests, you probably scored high in progressivism.

TPI Profile Sheet

Thank you for taking the TPI. Your results are represented on the graph below. For information on how to interpret your results, please see the [Interpretation page](#)



(retrieved from www.teachingperspectives.com, 2017)

Appendix E

PowerPoint Presentation: Listen to the Music, Representation of Learning

Listen to the Music

Representation of Learning, EDUC 5P35, Ed Enns

Don't you feel it growin', day by day People gettin' ready for the news Some are happy, some are sad Oh, we got to let the music play	What the people need Is a way to make 'em smile It ain't so hard to do if you know how Gotta get a message Get it on through
--	--

(The Doobie Brothers, 1972)

- I enjoy narratives shared through music. I feel like they connect me to people and ideas from around the world. I believe music provides a powerful medium for sharing our thoughts, ideas and stories.
- Music helps people figure out who they are-and, just as importantly, who they are not. (Frith in Lippman & Greenwood, 2012)

What is education like for most adults today?

We don't need no education
We don't need no thought control
No dark sarcasm in the classroom
Teacher leave them kids alone
Hey! Teacher! Leave them kids alone!
All in all it's just another brick in the wall
All in all you're just another brick in the wall
(Pink Floyd, 1979)

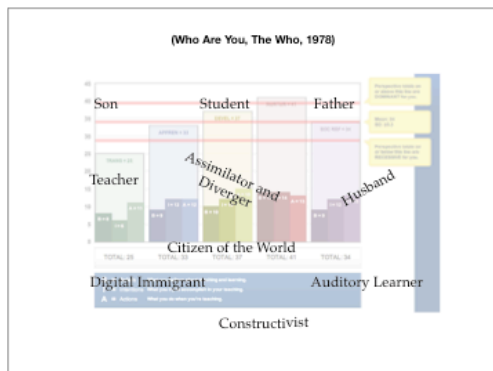
- Today's students are no longer the people our educational system was designed to teach. (Prensky, 2001)
- Between 70 and 90 percent of professors use the traditional lecture as their primary instructional strategy. (Gardiner, 1998)
- The amount of time spent listening is negatively related to change in critical thinking and positively related to memorizing. (Smith in Gardiner, 1998)

So how do we change things?

(Changes, David Bowie, 1971)

- I believe change needs to come from the front lines, from the hearts and minds of teachers and students. I believe the "music" they make has the power to transform a system.
- Teachers must be lifelong learners and students must be leaders of instruction. A hermeneutic circle must be formed in classrooms where the discourse is shared, empowering, emerging and tentative. . . . Postmodernism cannot be imposed uniformly, but it can provide the philosophical support for a change in consciousness that will necessarily lead to new practices. (Slattery, 2013)
- But how do I start?

- By getting to know who I am and what I believe about education.
- Self reflection can lead to significant personal transformations. (Mezirow, 1997)
- We teach who we are. (Palmer, 2008)
- So . . . Who are you?



- Teaching holds a mirror to the soul. If I am going to look in that mirror, and not run from what I see, I have a chance to gain self-knowledge and knowing myself is as crucial to good teaching as knowing my students in my subject. (Palmer, 2008)
- Brookfield (2002) encourages us to teach reflectively by researching assumptions in our teaching through different lenses including the lens of our students' eyes.
- I must be willing to engage students at a level of discussion where who they are is more important than the content of course. (Curran Doige, 2003)
- We need to put the pieces together to become one learning community.

Imagine what adult
education could be . . .

(Imagine, John Lennon, (1971)

One of the most
valuable actions we
could take to improve
learning—and thus
the productivity of
both our students and
our institutions—
would be to teach our
students how to learn.

(Gardiner, 1998)

- Teachers and parents are encouraged to become mentors and guides who will inspire students to seek wisdom and understanding as part of a community of learners. In postmodern schooling, teachers, administrators and parents will recognize that they are not experts with all the answers but fellow travelers on the lifelong journey of learning. (Slattery, 2013)



- To sum up, consider Dewey's suggestion that an educated person is one who has "gained the power of reflective attention, the power to hold problems, questions before the mind." (Kohn, 2003)
- How will you help your students discover the "power" within each of them?
- Enjoy composing your "songs" and listening to the "songs" of your students. I'm sure you will make beautiful music together.

Then you hear the music and it all comes crystal clear
The music does the talkin' says the things you want to hear
I'm young, I'm wild and I'm free
I got the magic power of the music in me
(Triumph, 1981)

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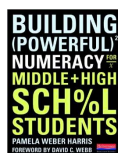
Appendix F

PowerPoint Presentation: Collaborative Inquiry for Learning Mathematics

Collaborative Inquiry for Learning Mathematics

Algorithms

"We should study why these processes work. However, how often should we actually use them? In today's world, we have other, even quicker and more accurate methods of computing when we are faced with dealing with many large numbers. If the algorithms are students' only computation strategy, the algorithms' digit approach may inadvertently affect students' progress in higher math."



(p. 4, Weber Harris, Building Powerful Numeracy for Middle and High School Student, 2012)

Focus/Leadership Math Project

- exploring beliefs/practice/cultures
- classroom based learning combined with content
- customized to meet your needs
- data is gathered to determine what works

Group Norms

- Work from an asset model - focus conversations on what students know and can do. Recognize 'growth mindset' thinking.
- Commit to actively participating by sharing ideas and listening actively. Respect others when they are talking, and always assume the best intentions
- Honour each other's experiences - recognize that we are all on a learning journey. Learning Stance vs. Performance/Evaluation Stance.
- Take risks and honour each other's opinions - be open to providing and receiving feedback
- Be open to new ideas and different approaches. Base new learning in current research.

Agenda

8:35	Welcome and introductions
	Mini Lessons
	PD - Comprehensive Mathematics/Practice/Homework
9:45	Co-planning the first two parts of the three lessons
11:15	Co-teaching the first two parts of the lessons
11:55	Lunch
12:35	Co-planning part 3 of the lesson based on the student work and the insiders' observations
1:25	Co-teaching part 3
1:45	De-briefing the lesson/Follow up ideas
2:25	Planning time (if needed)
2:55	Finish

Mini Lesson Books

- part of the Contexts for Learning Mathematics kits in your school (Addition & Subtraction, Multiplication & Division)
- teaching basic facts and mental math through conceptual understanding and thinking
- providing additional copies of all mini-lesson books for math focus schools - total of 6 copies of each book
- 10 minutes daily instruction recommended

$$150 \div 15$$

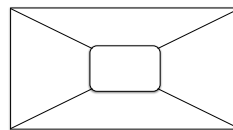
$$300 \div 15$$

- What possible questions could come after this one in the string?
- What strategy, model or important idea could be addressed during this string?

Reconnecting

- Have you tried a mini lesson?
- How is teaching through Problem Solving going?
- Successes/Questions/Challenges

Comprehensive Mathematics Program



- What are the main components of a "Comprehensive Mathematics Program"?
- Use a placemat to record the group's thinking
- Brainstorm and try to agree on 2 - 5 components of a Comprehensive Mathematics Program

Comprehensive Mathematics

- Problem-based learning focused on conceptual understanding and application of skills in context
- Engaging student in mathematical learning and building a "growth mindset"
- Purposeful practice for consolidation
- Integration of mathematical skill development (e.g., fluency and automaticity, mental mathematics, estimation skills)

"The key is to specify a goal that clearly identifies what students are to know and understand about mathematics as a result of their engagement in a particular lesson."

p. 13, Smith and Stein, *5 Practices for Orchestrating Productive Mathematics Discussions*, 2011

Purposeful Practice



(Pfohl, 2010)

1. What is the learning focus?
2. Design some practice questions that could follow this activity.

Agenda

- 8:35 Welcome and introductions
- Mini Lessons
- PD - Comprehensive Mathematics/Practice/Homework
- 9:45 Co-planning the first two parts of the three lessons
- 11:15 Co-teaching the first two parts of the lessons
- 11:55 Lunch
- 12:35 Co-planning part 3 of the lesson based on the student work and the insiders' observations
- 1:25 Co-teaching part 3
- 1:45 De-briefing the lesson/Follow up ideas
- 2:25 Planning time (if needed)
- 2:55 Finish

Today's Classrooms

Co-planning

- What did the host teacher do in the last class?
- What were the students' strengths? needs?
- What curriculum expectation(s) will you select for today's problem?
- What will the lesson focus be?

Co-planning Pt 2

- Decide on a problem. Ensure there will be a variety of ways to solve it.
- Solve the problem ourselves (individually) to get an idea of what we might get in the classroom
- Look at our work and decide if the problem meets our learning focus. What student strategies do we expect?

Co-planning pt 3

- Use the planning template to describe the Getting Started and Working On It lesson components.
- Choose roles, gather notebooks, chairs if needed and help the host teacher get ready

Roles

- Lead Teacher - facilitates the lesson, usually the host teacher but could be another teacher, administrator, consultant
- Co-Teacher - assists by asking students questions and supporting the lead teacher
- Silent Observers - watches one group of students and records observations without interaction with stu

Agenda

8:35	Welcome and introductions
	Mini Lessons
	PD - Comprehensive Mathematics/Practice/Homework
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1:25	Co-teaching part 3
1:45	De-briefing the lesson/Follow up ideas
2:25	Planning time (if needed)
2:55	Finish

Sharing

- Share your observations from the lesson. Have the student work on the table as you share.
- 1. Observers
- 2. Lead and Co teachers
- 3. General Observations

Co-planning the Reflect & Connect

- What is the learning focus for this part of the lesson?
- Choose 1-3 pieces of student work you will use to highlight the learning for your students.
- Consider only using parts of a student's solution to focus and bring out an important idea.
- Decide in what order you will share the work.
- Consider what teacher annotations you might want to make.
- Plan a practice question for students that will take about 5-10 minutes.

Sharing

Share your observations from the reflect and connect.

- 1. Lead and Co teachers
- 2. Observers
- 3. General Observations
- Brainstorm some next steps for the host teacher.

- ## Evaluation Tool Limitations

Evaluation Tool – Suggested Adaptations

- Use multiple observers over a number of visits to increase reliability (p.30, Ho & Kane, 2013)
- Develop scales that allow for clearer distinctions in teaching performances
- Use more specific language in describing the competencies to promote greater reliability
- Create subject specific expectations or competencies rather than general ones (p. 7, Paulsen, 2002, p. 31, Ho & Kane, 2013)

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Appendix H

Essay: Evaluating Who We Are

Evaluating Who We Are

Ed Enns, B.A., B.Ed.

Department of Graduate and Undergraduate
Studies in Education

Submitted in partial fulfillment
of the requirements for EDUC 5P87

Faculty of Education, Brock University
St. Catharines, Ontario

© Ed Enns 2014

In 1997 Palmer wrote an article concerned with identifying the foundational components of effective teaching. The subtitle of the article was “We teach who we are.” (p. 14). He posits that knowledge about the self, including personal beliefs and philosophies about teaching and learning, is an important part of becoming a more effective teacher. If this is true, then should the examination of teaching and learning philosophies not be a fundamental part of the teacher evaluation process for both the evaluator and the teacher being evaluated?

In this paper I will explore this question by sharing my experiences of modifying the Ontario Ministry of Education Summative Report Form (OMESRF) through the lens of my own teaching philosophies. A copy of the modified OMESRF follows in the Appendix. I will relate the changes I have made to this evaluation form to my beliefs in teaching and learning to support the idea that an evaluator’s teaching philosophy will impact judgments and decisions being made during teacher evaluations and therefore should be shared during the evaluation process. I will also explore the idea of including the identification of the teacher’s education philosophy as a necessary component of the evaluation process. I conclude by suggesting the most effective forms of teacher evaluation must include reflecting on who we are and I will share questions for future research consideration.

What Do I Believe About Teaching and Learning?

In order to understand and examine my own beliefs about teaching and learning I used two different teacher inventory surveys from Leahy (1995) and Pratt (2001). The two inventories complimented one another by providing similar results and conclusions about my educational beliefs. The Leahy inventory identified Reconstructionism,

Progressivism and Existentialism, as my dominant educational philosophies while the weakest were Behaviourism, Essentialism and Perennialism. The Pratt inventory identified the Nurturing perspective as dominant followed closely by the Developmental and Apprenticeship perspectives. My only recessive perspective was Transmission. So what does all this mean? To summarize, I believe that “effective teaching must be planned and conducted from the learners point of view” (Pratt, 2001, p. 3) and that “learners should be active and learn to solve problems by reflecting on their experience” (Leahy, 1995, p. 3). I don’t believe optimal learning occurs when “the emphasis is on intellectual and moral standards that should be transmitted by the schools”, nor do I believe that “the score of the curriculum should be essential knowledge and skills” (Leahy, 1995, p. 2).

As I reflected on my results from these inventories I found great resonance with the perspective and philosophy descriptions that were dominant in my thinking. I was surprised to realize that I couldn’t totally dismiss the ideas presented in my least dominant philosophies and perspectives. In the Pratt inventory, Transmission was my only recessive perspective yet I found myself agreeing with the lead sentence describing that perspective. “Effective teaching requires a substantial commitment to the content or subject matter” (p. 3). This realization helped me to consider the possible merits of educational perspectives and philosophies I may previously have dismissed.

What impact did my educational philosophy and beliefs have on the editing process of my evaluation form? Did the changes I made to this form only reflect the educational philosophies I strongly agree with or did they consider other perspectives?

Does An Evaluator's Educational Philosophy Create Evaluative Bias?

To answer these questions I will discuss and analyze some of the changes I made to improve the OMESRF (2010), through the lens of my teaching perspectives and philosophies as outlined in the Pratt and Leahy inventories. I will also consider these changes from educational perspectives that differ from mine.

The Purpose of Teacher Evaluation

Why do we evaluate teachers? I believe the goal of all teacher evaluation should be to improve teaching and learning. Who could argue with that? The philosophical differences begin when we start to consider the question of how to improve teaching. In essence, if evaluation is about improving teaching, then it is about teacher learning and therefore directly connected to our educational philosophy and beliefs about learning. My educational philosophy would suggest that to improve teaching through evaluation we should emphasize reflection on practice from the teacher's point of view. This philosophy would suggest an evaluative process that allows for dialogue about teaching and next steps for improvement. Someone with a different perspective may suggest that the teacher's point of view doesn't matter he or she just need to follow the standards of practice as outlined by the educational institution. This philosophy may suggest that teacher evaluation would consist of an administrator making quantitative judgments of teaching performances when compared to standards. These two different philosophies would generate two very different evaluation tools. A comprehensive evaluation tool would need to include a variety of evaluation data sources to honor different educational perspectives and philosophies of both evaluators and teachers.

Although the OMESRF is labeled as a summative evaluation I approached the editing process of this evaluation tool with formative and summative purposes in mind. I also attempted to address the evaluation needs of different educational perspectives.

Editing Process

The OMERSF is currently used by school principals or vice principals to provide a summative evaluation to all elementary and secondary teachers, in the province of Ontario every five years. I used the existing form to evaluate a video taped grade five math lesson (Bedley, 2012). During this evaluation process, I noted limitations found within the form based on some of the literature I reviewed during this course (Berk, 2005; Chikering & Gamson, 1987; Fink, 1999; Gates Foundation Measures of Effective Teaching Project, 2010-2013; Ho & Kane, 2013; Paulsen, 2002) and on my personal experiences as an elementary teacher and consultant. Two of my classmates in this course also provided suggestions for improvement. I then proceeded to edit the OMESRF in an attempt to address these limitations.

Resulting Changes and Philosophical Connections

The first major change I made to this form was to repurpose it from an observation tool to one that summarizes data from multiple sources for evaluation (Berk, 2005; Fink, 1999; Kane & Cantrell, 2013; Reddy et al., 2013). Currently the OMESRF uses teacher observation by one administrator as the sole data source. As Berk (2005) states, “given the complexity of measuring the act of teaching, it is reasonable to expect that multiple sources can provide a more accurate, reliable, and comprehensive picture of teaching effectiveness than just one source” (p. 49).

The inclusion of a variety of data sources also has the potential to address the evaluation needs that arise from different educational philosophies. If I believe in Essentialism and the “need for intellectual standards” (Leahy, 1995, p. 2) I can find evidence of progress against standards through the inclusion of pre and post student achievement data. In contrast, if I believe in Progressivism that “focuses more on the child than the subject matter” (Leahy, 1995, p. 3) I can use student perception data through surveys, interviews or focus groups. In editing the evaluation form, I included the direction that the teacher would select which evaluation tools to use in each data source. This direction arises from my Progressive philosophical stance of teachers being active in their own evaluation to learn from their experiences. Someone with more of a Transmission perspective may prefer to have the evaluator select the data sources.

The second major change I made to the OMESRF was to include a description of the teacher’s educational philosophy through the use of a tool such as the Leahy inventory. As an evaluator coming from a Developmental perspective I believe it is vital to know what an educator believes about teaching before I begin the evaluation. Understanding a teacher’s beliefs about teaching and learning will help me understand their instructional actions and strategies in the classroom. I also included instructions for the evaluator to complete the Leahy inventory to help define his or her educational philosophy. This information would be shared with the teacher being evaluated near the end of the evaluation process as a starting point for dialogue and reflection. An evaluator with an Essentialist philosophy may consider the idea of identifying educational beliefs as irrelevant if all teachers only need to attend to following the rules of best practice. In my experience as an elementary mathematics consultant I have found it extremely

difficult to begin discussions about changes in teaching pedagogy without first reflecting on our beliefs about how students learn. If someone with an Essentialist philosophy were evaluating me it would still be helpful to know his or her educational philosophy to understand the perspective from which I was being evaluated.

There will always be some bias involved in the evaluation process that will be related to the evaluator's educational philosophy and beliefs. That bias can be minimized by providing a variety of data sources in the evaluation process and through discussions between the evaluator and the teacher through which educational philosophies can be shared as a starting point to determine next steps.

Considerations During the Editing Process

The OMESRF form contains sixteen competencies that are to be used to assess teacher performance. While I was using the form as an observation tool to evaluate a video lesson I felt the competencies were too general and needed more subject specific descriptors. By changing the purpose of this form to a summary of multiple data sources the general language of the competencies seemed appropriate. In order to complete this edited summary evaluation form the results from a variety of different individual evaluation tools will be considered.

Differences in educational philosophy will become more pronounced during the creation and use of individual evaluation tools with more specific purposes such as observation. In my search for an evaluation tool specific to elementary mathematics I found an existing tool that was used in the Gates Foundation research on elementary teacher evaluation (Ho & Kane, 2013). The Mathematical Quality of Instruction tool (MQI) was developed at Harvard University between 2003 and 2010. I registered for

online training in the use of the MQI instrument. At the beginning of the training I was informed that I would need to let go of my personal beliefs about effective math instruction and adopt those presented in the MQI tool in order to use the evaluation tool. In essence, I was being forced to adopt someone else's educational beliefs about how mathematics should be taught. I found as the MQI tool became more specific and detailed about the desired teacher actions this increased the chance for philosophical discord. I preferred a more general observation tool such as Danielson's Framework for Teaching (2013). This tool provided more general descriptors and statements that allow for more of a variety of teaching approaches and therefore was more inclusive of different educational perspectives.

The sharing and discussion of educational philosophies will be essential in the creation and application of teacher evaluation tools such as student surveys, observational tools, and portfolios.

Conclusions

The purpose of formative and summative teacher evaluation should be to improve teaching. If "good teaching cannot be reduced to technique" and "good teaching comes from the identity and integrity of the teacher" (Palmer, 1997, p.14) then the evaluation process must include a description of our educational philosophies and beliefs as a starting point for reflection and growth for both evaluator and teacher.

Many questions remain for consideration for future research. How do we improve teaching? Are some educational philosophies and perspectives more effective than others? Does this change according to discipline? Is it possible for teachers with different

educational philosophies to be equally effective? What happens when recommended teaching practices conflict with a teacher's personal educational philosophy?

The inclusion of educational philosophy descriptions in teacher evaluation tools could provide answers to these questions. If we really want honest dialogue about improving instruction then teacher evaluation needs to start with who we are and what we believe.

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Appendix

* identifies changes made to this form



Ministry of Education

Overall Summative Report Form for Experienced Teachers (Approved Form)

This form must be used for each performance appraisal. The duties of the principal may be delegated to a vice-principal in the same school or to an appropriate supervisory officer.

Boards are not allowed to remove any of the content from this approved form. Boards may add information, such as additional competencies (see section 277.32 of the *Education Act*), as long as this does not affect the substance of the form or mislead, and as long as the form is organized in substantially the same way as the approved form

Teacher's Last Name

Teacher's First Name

Principal's Last Name

Principal's First Name

Name of School

Name of Board

Description of Teacher's Assignment (grade(s), subject(s), full-time/part-time, elementary/secondary, etc.)

***Selection of Evaluation Components (teacher to select a minimum of one from each category)**

Observation	Student Achievement	Student Perceptions	Self Evaluation
<input checked="" type="checkbox"/> Administrator (mandatory) <input type="checkbox"/> 2 nd Administrator <input type="checkbox"/> Peer <input type="checkbox"/> Knowledgeable <input type="checkbox"/> Other	<input type="checkbox"/> Pre-Post year to year <input type="checkbox"/> Pre-Post within year <input type="checkbox"/> Pre-Post observational data <input type="checkbox"/> Other	<input type="checkbox"/> Student Survey <input type="checkbox"/> Parent Survey <input type="checkbox"/> Student Focus Group <input type="checkbox"/> Student Interview <input type="checkbox"/> Other	<input type="checkbox"/> Portfolio <input type="checkbox"/> Video/Audio Tape <input type="checkbox"/> Reflective Journal <input type="checkbox"/> Other

***Description of Teaching Philosophies (using the Leahy Philosophic Inventory, (Leahy, 1995))**

Instructions to the Principal

1. This report must be completed after the post-evaluation meeting.
2. A copy signed by the principal must be provided to the teacher within 20 school days of the classroom observation. If the rating is *Unsatisfactory*, the principal must follow the steps outlined in section 12.3.2 of the *Teacher Performance Appraisal Technical Requirements Manual* (2010).
3. The teacher may add comments and must sign this report to acknowledge receipt. At the request of either the teacher or the principal, the teacher and the principal must meet to discuss the performance appraisal after the teacher receives a copy of this report.
4. A copy of this report signed by both the principal and the teacher must be sent to the appropriate supervisory officer.
5. In preparing the summative report, the principal must:
 - *consider all components of the evaluation as self-selected by the teacher;
 - consider all 16 competencies in assessing the teacher's performance;
 - provide comments regarding the competencies identified in discussions with the teacher as most relevant to the teacher's performance appraisal;¹
 - *complete the Leahy inventory and a description of educational philosophy
 - *provide comments regarding the connections between teaching philosophies and the competencies through discussion with the teacher and provide possible next steps for reflection
 - provide an overall rating of the teacher's performance in accordance with the rating scale;
 - recommend professional growth goals and strategies for the teacher's development.

¹ Notwithstanding the discussions held between the teacher and the principal, the principal is required to assess teacher performance in relation to all 16 competencies set out in Schedule I of O. Reg. 99/02, as amended, and may comment on competencies other than those discussed.

Appendix B cont'd**Instructions to the Principal:**

*Comment and provide evidence on competencies identified in discussions with the teacher as the focus of the teacher's performance appraisal (the principal may also comment on other competencies that were assessed during the performance appraisal).

Domain: Commitment to Pupils and Pupil Learning *(select applicable competencies)

- ☐ The teacher demonstrates commitment to the well-being and development of all pupils.
- ☐ The teacher is dedicated in his or her efforts to teach and support pupil learning and achievement.
- ☐ The teacher treats all pupils equitably and with respect.
- ☐ The teacher provides an environment for learning that encourages pupils to be problem-solvers, decision-makers, life-long learners, and contributing members of a changing society.

Domain: Professional Knowledge *(select applicable competencies)

- ☐ The teacher knows his or her subject matter, the Ontario curriculum, and education-related legislation.
- ☐ The teacher knows a variety of effective teaching and assessment practices.
- ☐ The teacher knows a variety of effective classroom management strategies.
- ☐ The teacher knows how pupils learn and the factors that influence pupil learning and achievement.

Appendix B cont'd**Domain: Teaching Practice *(select applicable competencies)**

- ☐ The teacher uses his or her professional knowledge and understanding of pupils, curriculum, legislation, teaching practices, and classroom management strategies to promote the learning and achievement of his or her pupils.
 - ☐ The teacher communicates effectively with pupils, parents, and colleagues.
 - ☐ The teacher conducts ongoing assessment of his or her pupils' progress, evaluates their achievement, and reports results to pupils and their parents regularly.
 - ☐ The teacher adapts and refines his or her teaching practices through continuous learning and reflection, using a variety of sources and resources.
 - ☐ The teacher uses appropriate technology in his or her teaching practices and related professional responsibilities.
-

Domain: Leadership and Community *(select applicable competencies)

- ☐ The teacher collaborates with other teachers and school colleagues to create and sustain learning communities in his or her classroom and school.
 - ☐ The teacher works with other professionals, parents, and members of the community to enhance pupil learning, pupil achievement, and school programs.
-

Domain: Ongoing Professional Learning *(select applicable competencies)

- ☐ The teacher engages in ongoing professional learning and applies it to improve his or her teaching practices.

Connections between Teaching Philosophies and Competencies*Overall Rating of Teacher's Performance**

(Check the appropriate box.)

- ☐ *Satisfactory* ☐ *Unsatisfactory* (If the teacher receives an *Unsatisfactory* rating, an Improvement Plan will also be developed.)

Comments on the Overall Rating of the Teacher's Performance

If the teacher receives a *Satisfactory* rating, the principal is encouraged to provide further feedback on strengths and possible areas of growth for the teacher.

Appendix B cont'd

Professional Growth Goals and Strategies for the Teacher (required, if rating is *Satisfactory*)

The following professional growth goals and strategies are recommended for the teacher to take into account when developing his or her Annual Learning Plan (ALP).

Principal's Additional Comments on the Appraisal (optional)**Teacher's Comments on the Appraisal (optional)****Principal's Signature**

My signature indicates that this performance appraisal was conducted in accordance with Part X.2 of the *Education Act* and Ontario Regulation 99/02 and Ontario Regulation 98/02, as amended.

X

Date (yyyy/mm/dd)

Teacher's Signature

My signature indicates the receipt of this summative report.

X

Date (yyyy/mm/dd)